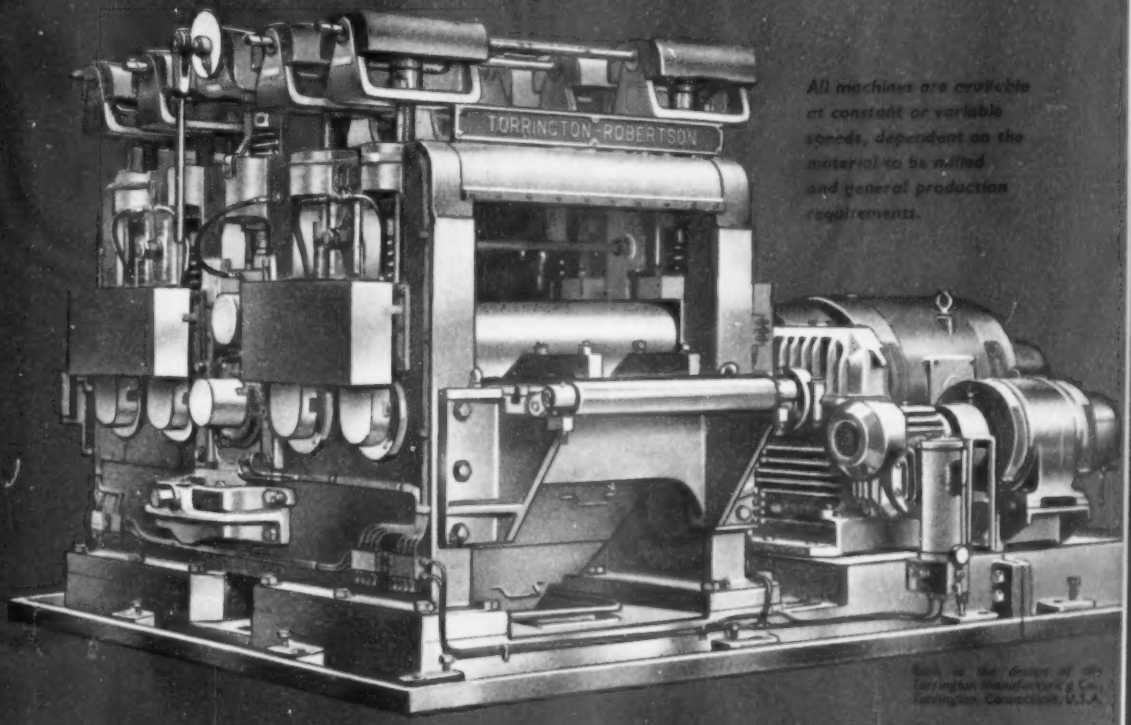
Sheet Metal Industries

The only Journal in the World wholly devoted to the Manufacture, Manipulation, Fabrication, Welding, Assembly and Finishing of Ferrous and Non-Ferrous Sheet and Strip

VOL. 38 : No. 413 SEPTEMBER 1961 PRICE 2/6

ROBERTSON

Slab Milling Machines are manufactured in a standard range of sizes suitable for overhauling non-ferrous strip from 6 in. to 44 in.



All machines are available at constant or variable speeds, dependent on the material to be milled and general production requirements.

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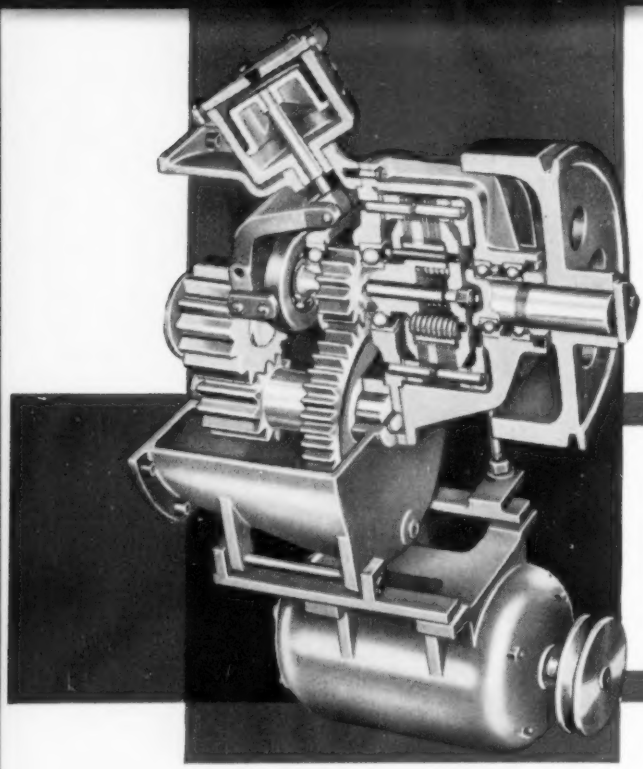

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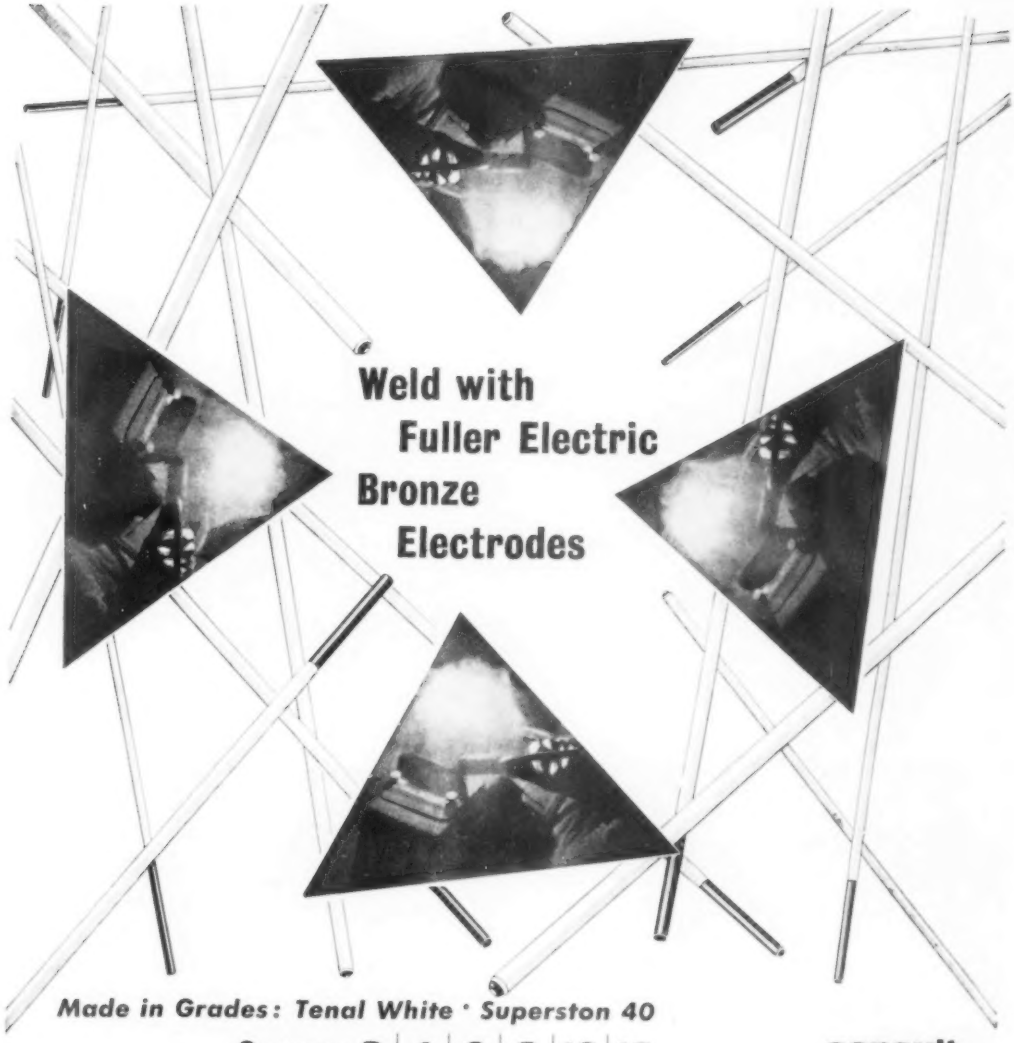

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Editorial Contents: 617, 619

Classified Advertisements: 119 to 123

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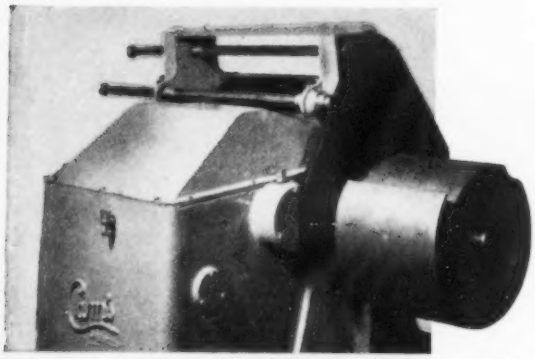
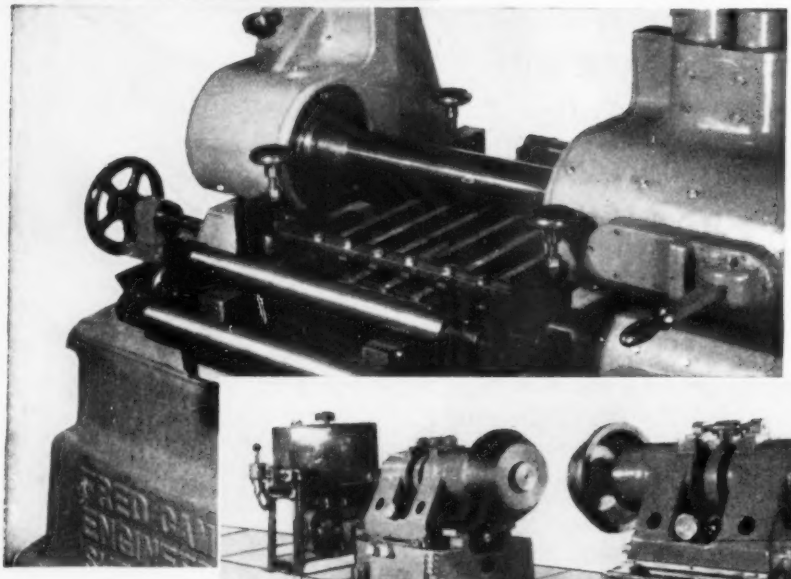
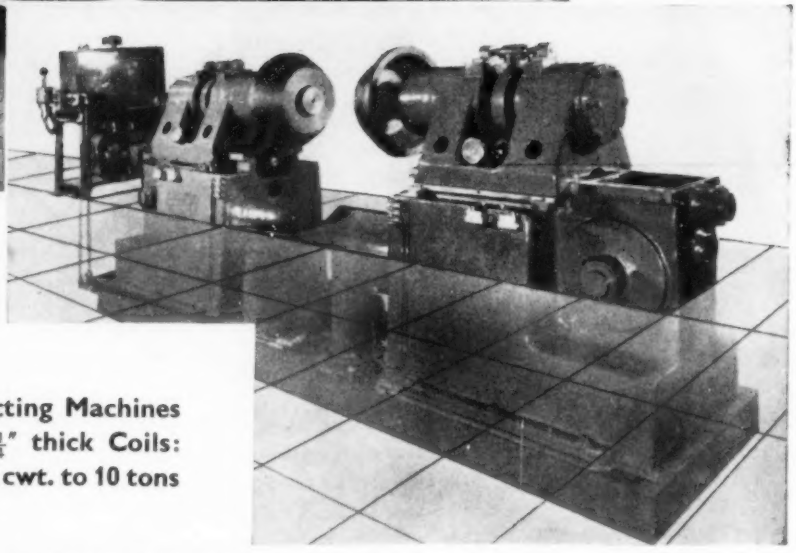


Cam's of SHEFFIELD

Auxiliary Equipment for Strip Mills, Box and Tube Works





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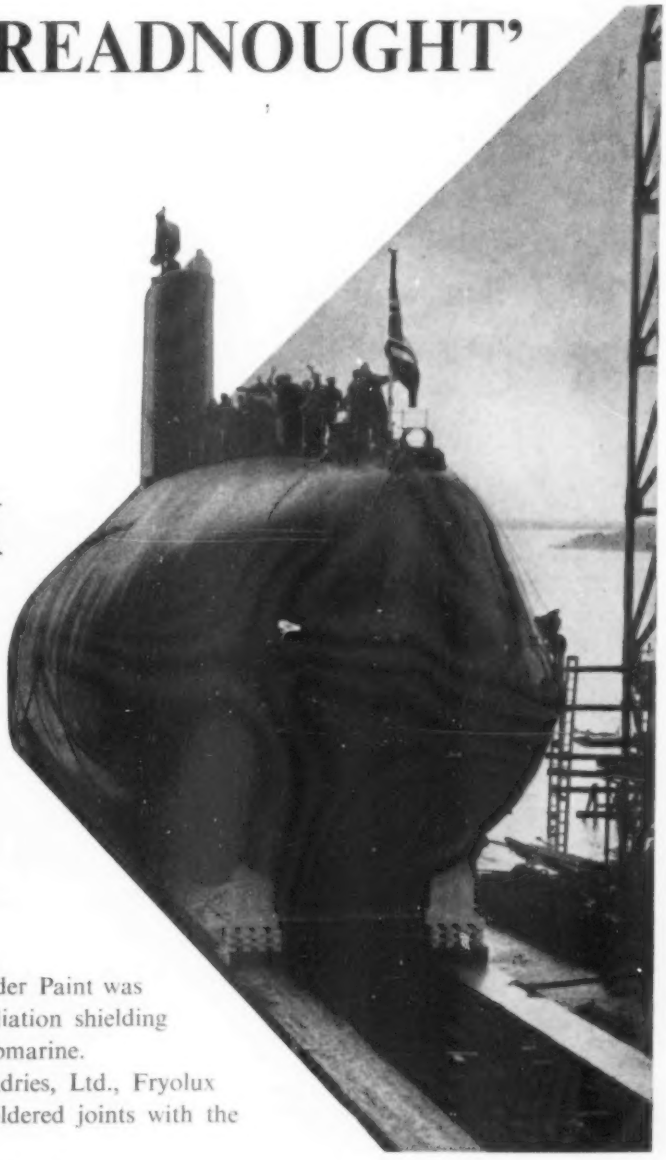

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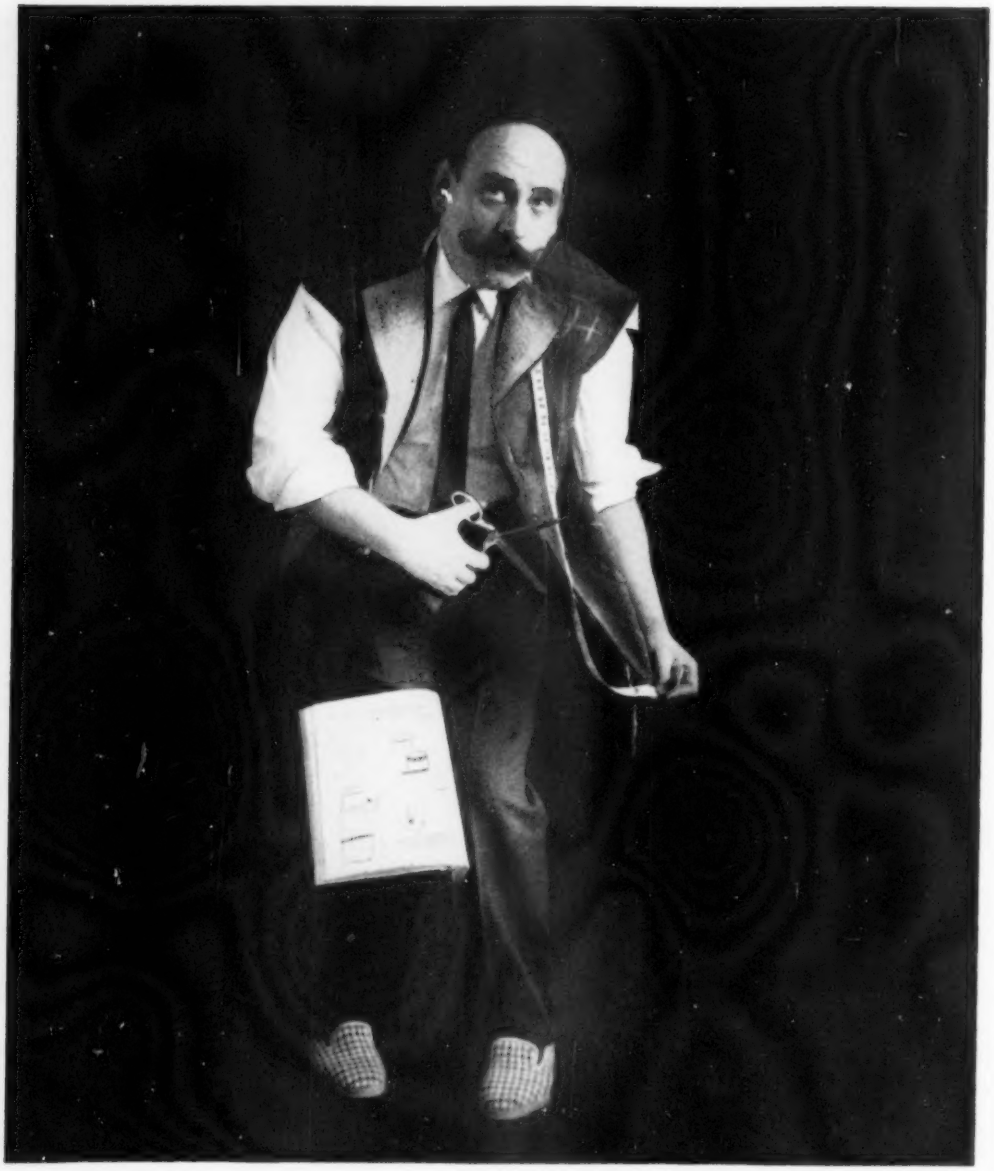

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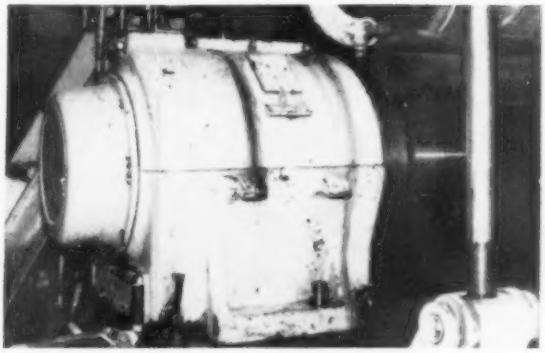

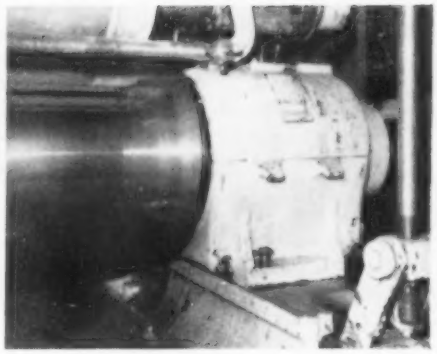

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KEEPS MASSIVE "SUPERCALENDER" GOING

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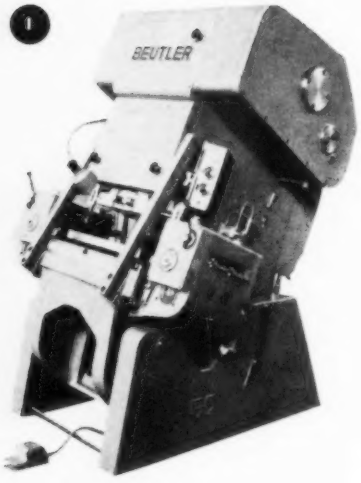

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- Presses are extremely rigid—possess no deflection.
- Stroke rates are infinitely variable from 66 to 200 strokes per minute.
- Full range of mechanical presses from 5 tons to 200 tons.

Sample components will astound you —ask to see them!

KIMBELL MACHINE

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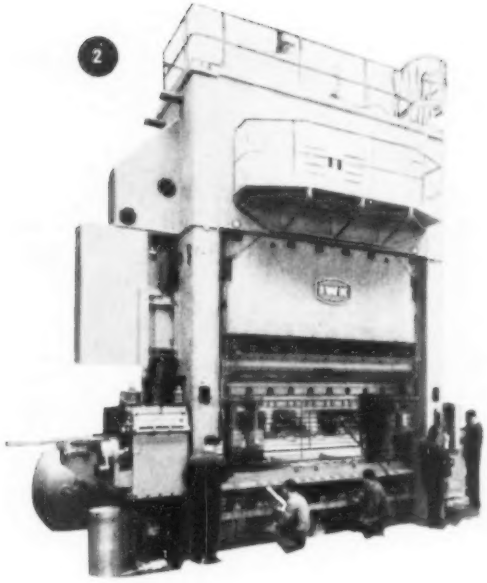

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THE NEW 550 TON TRANSFER PRESS

Finishes very large components with every stroke of the press.

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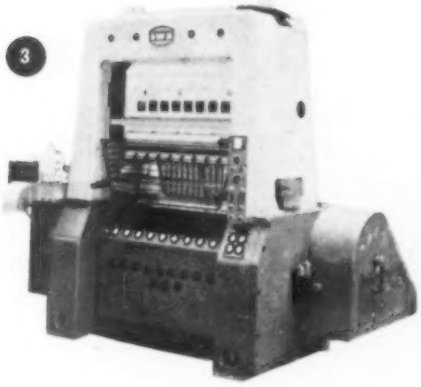
- Vibrations are eliminated—resulting in longer tool life.
- Presses are equipped with automatic safety devices which check correct transfer from one station to another etc. Press stops instantly in any emergency.



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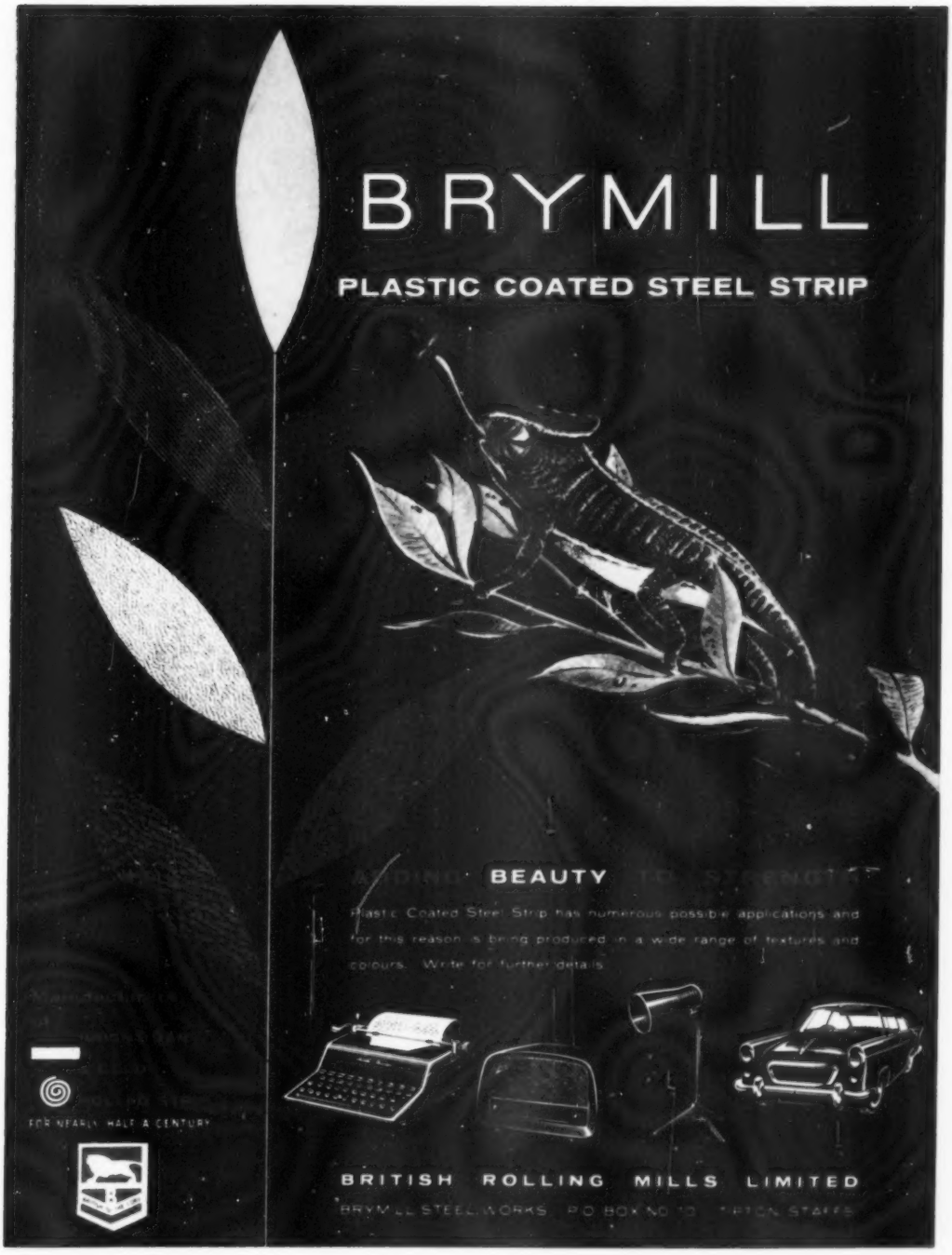
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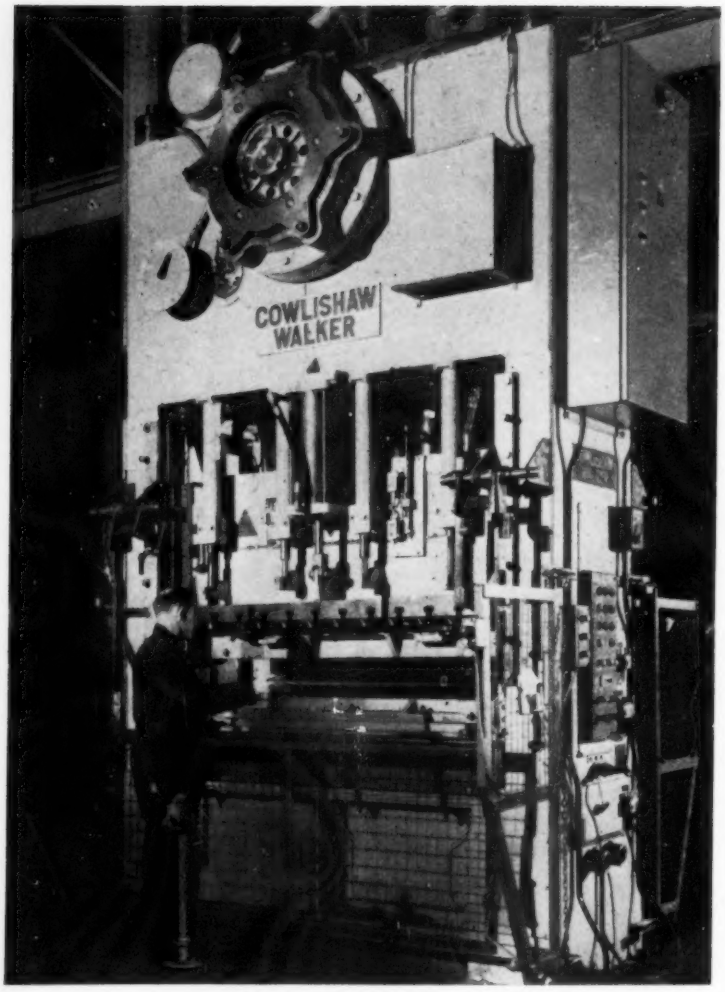

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Here is a new Bliss Press with features to boost

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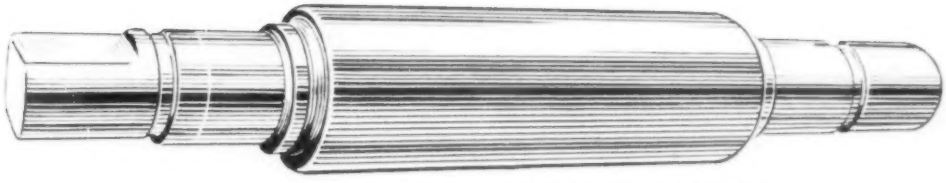

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547

Here is a new Bliss Press with features to boost production and cut operating costs. These presses have been designed for use where holes are to be punched or blanks cut at a distance from the edge of a wide sheet. The range includes two bench models of 2½ and 5½ tons capacities and six floor models in capacity ranges 10-60 tons. All complete with parts interchangeable with Bliss Bench and Inclinable Presses of similar tonnages.

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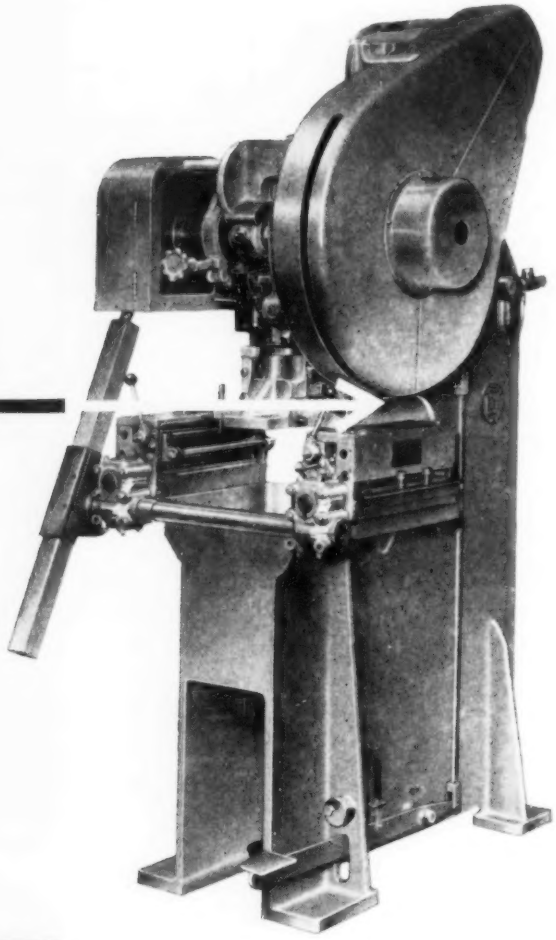

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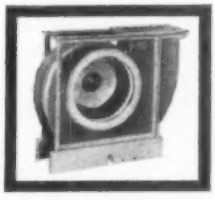

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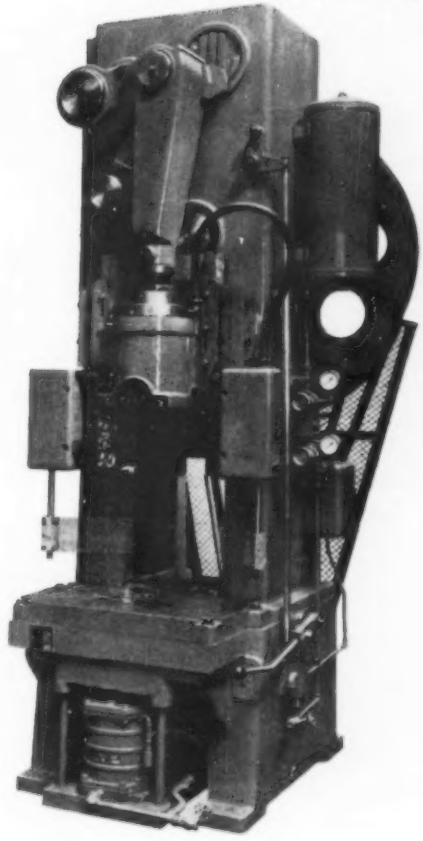

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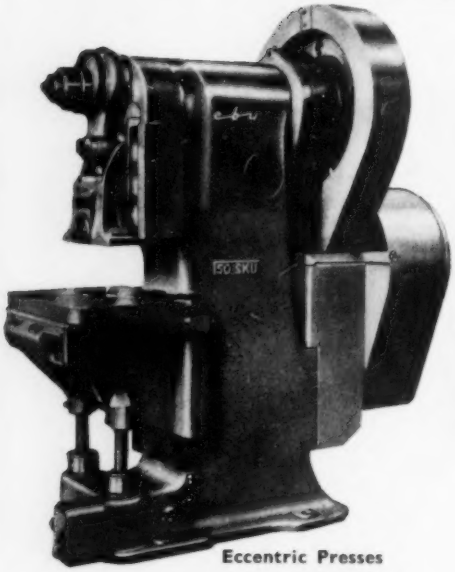
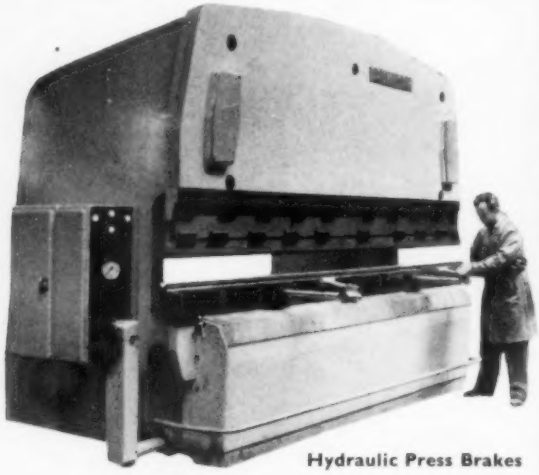


Eccentric Presses



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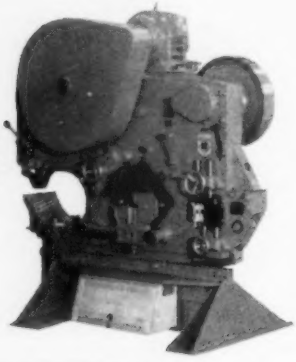
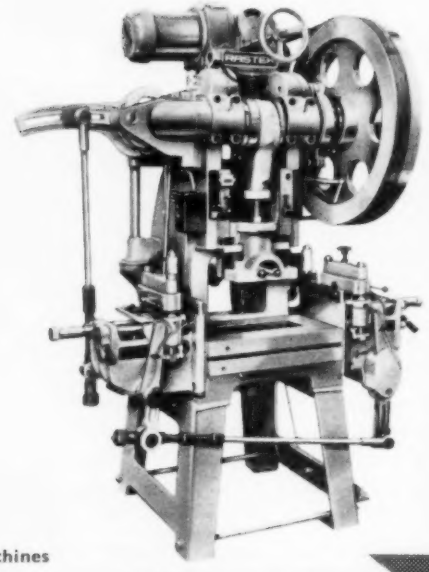
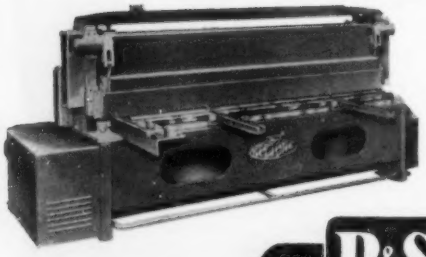
Universal Steel Workers and Single Purpose Machines





Precision Punching Presses



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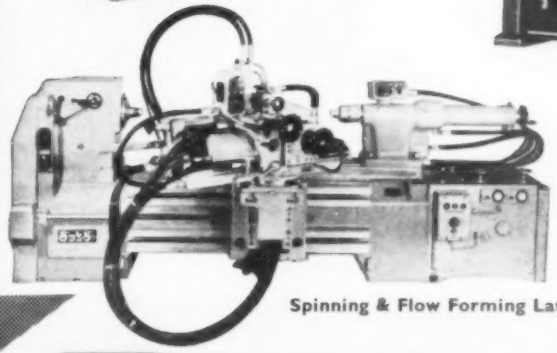

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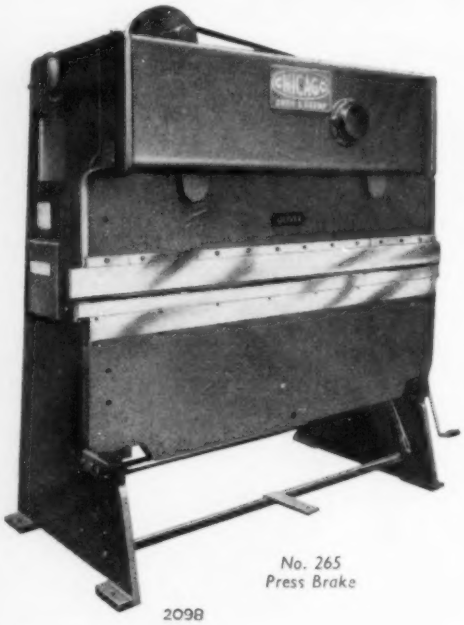

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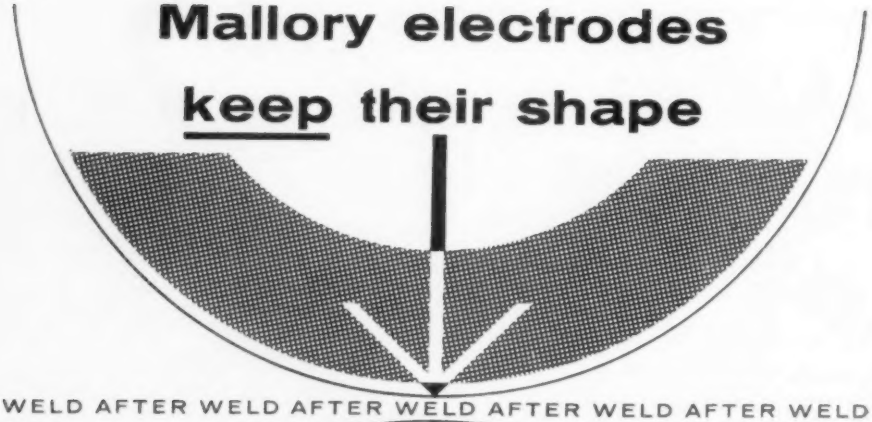

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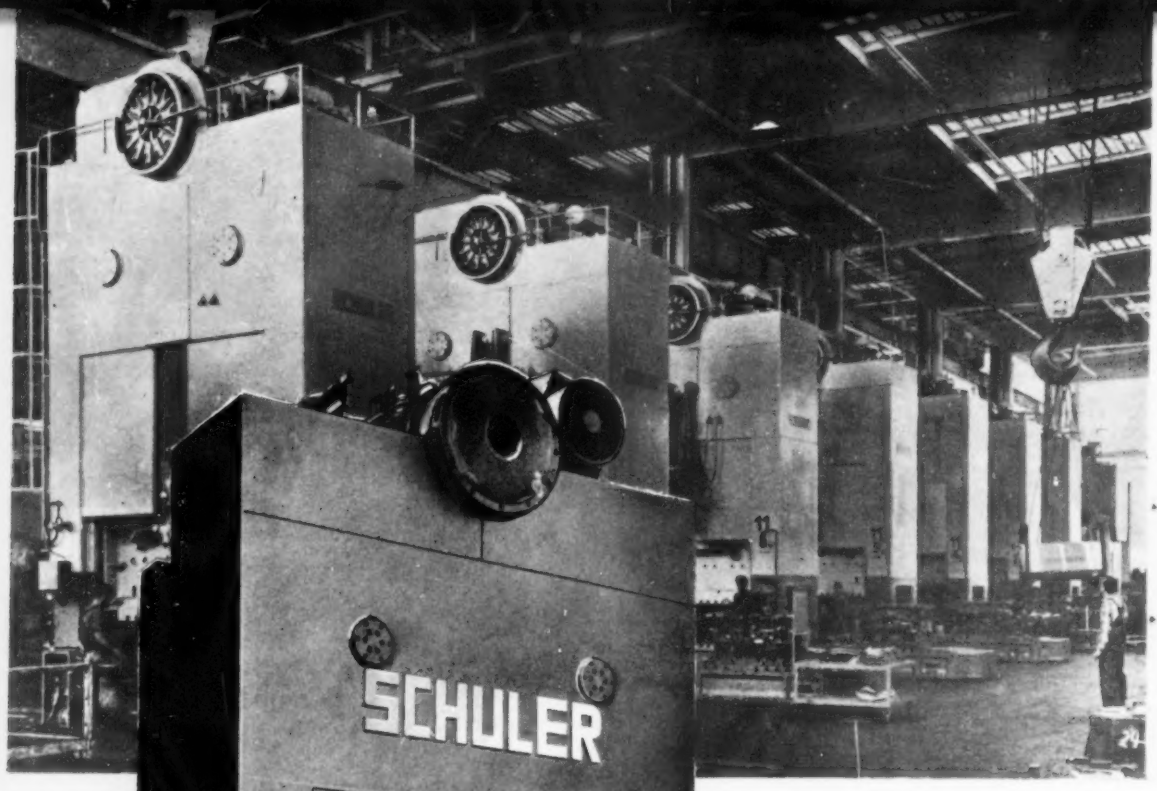

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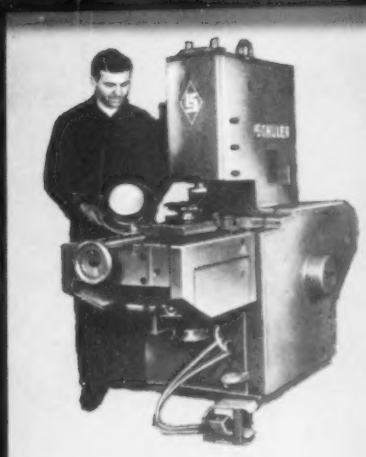

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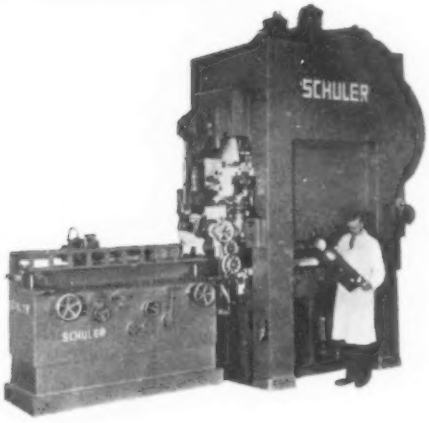

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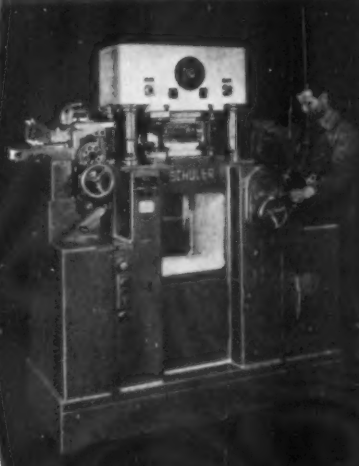

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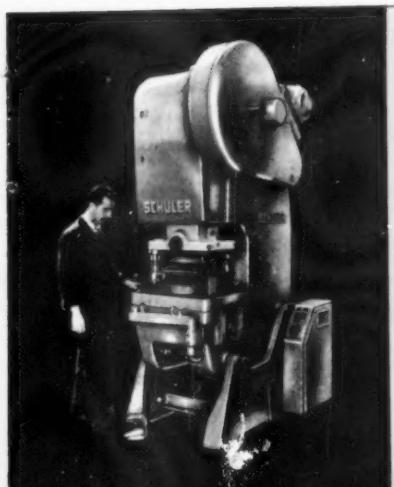

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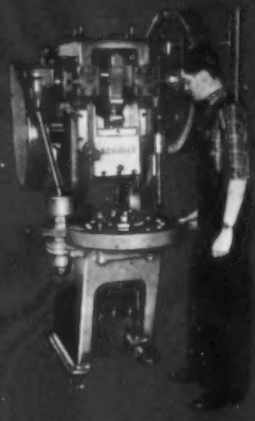

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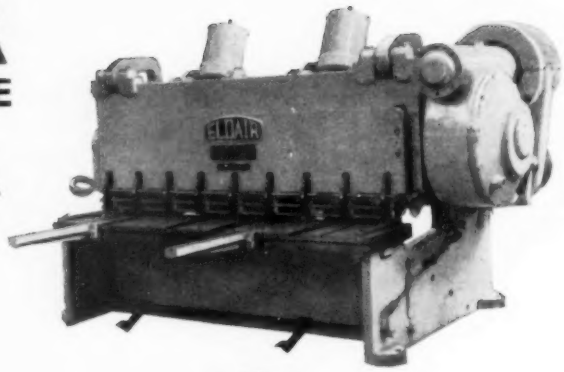

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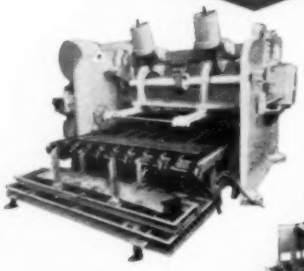

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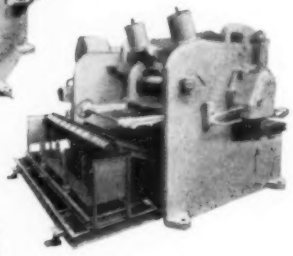

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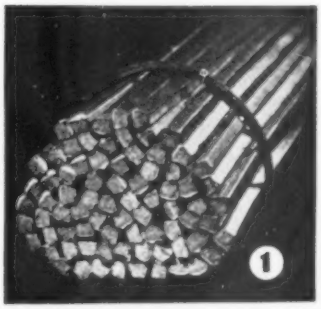

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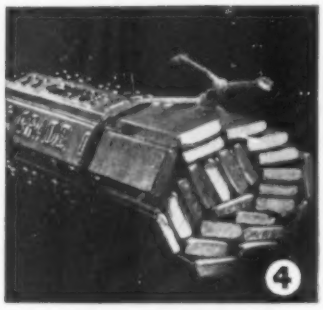

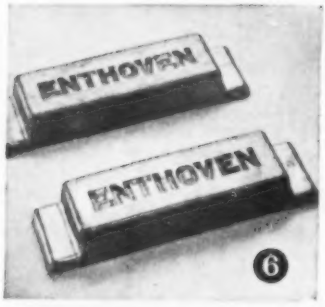

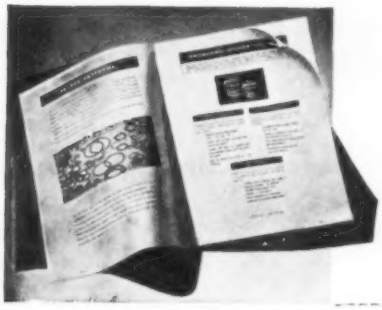

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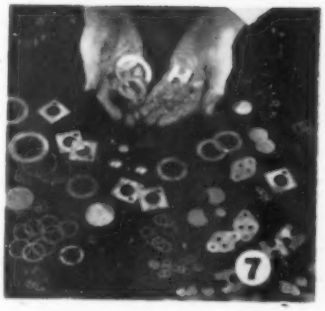

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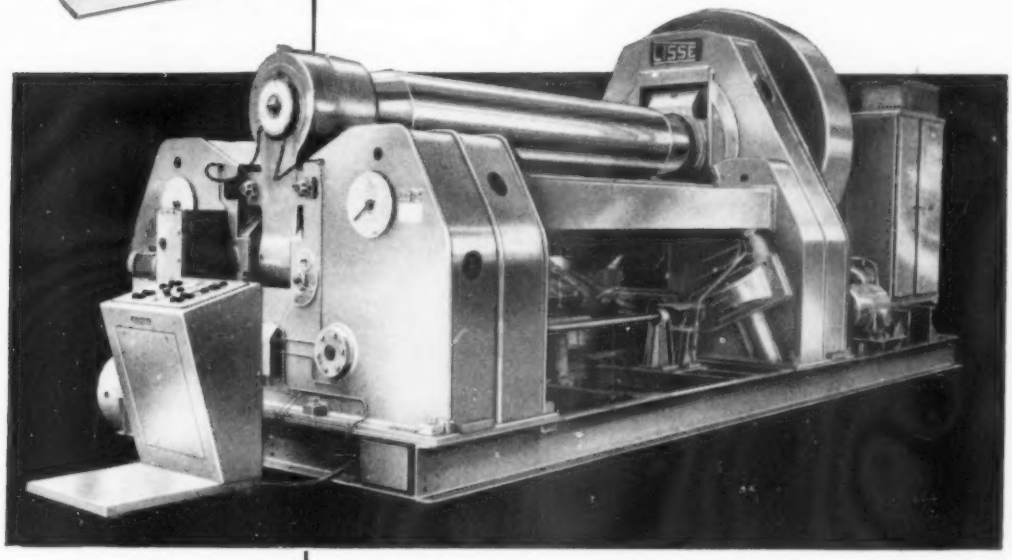

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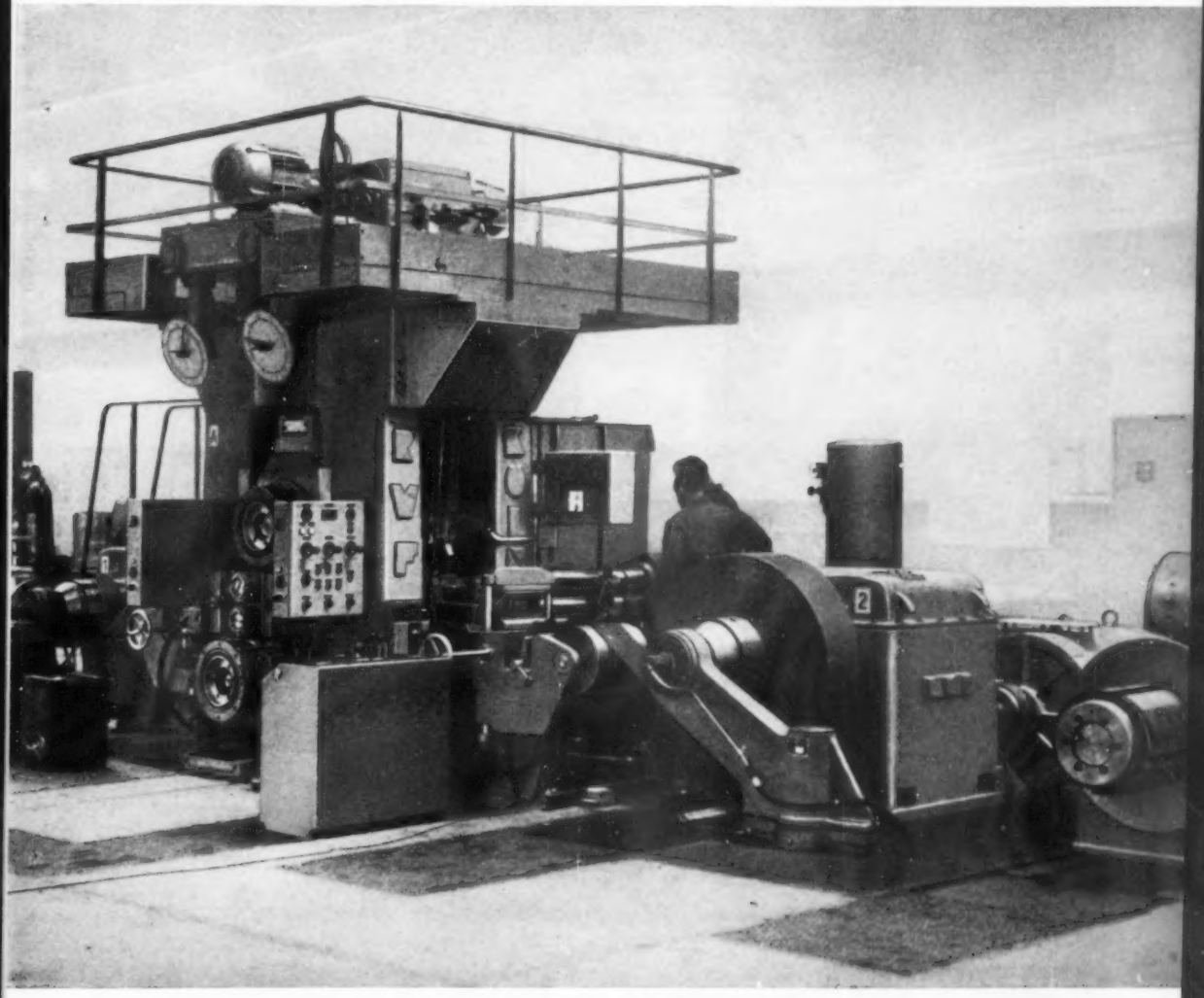

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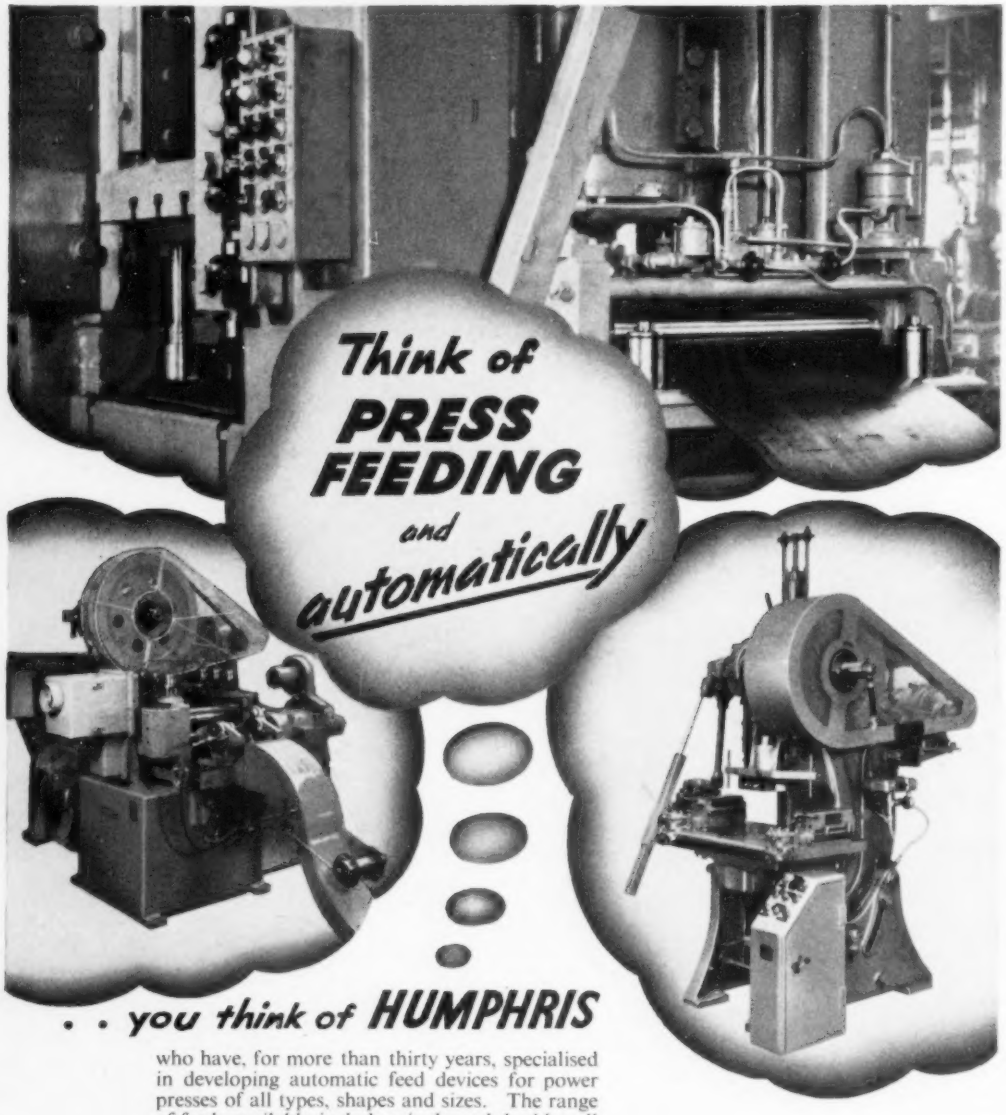

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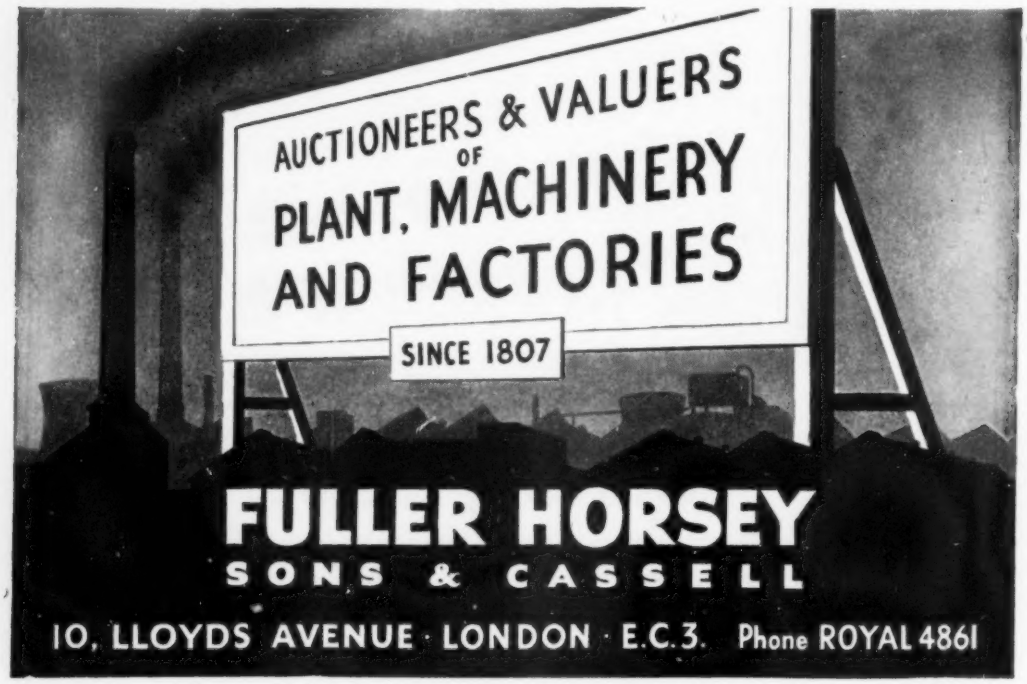

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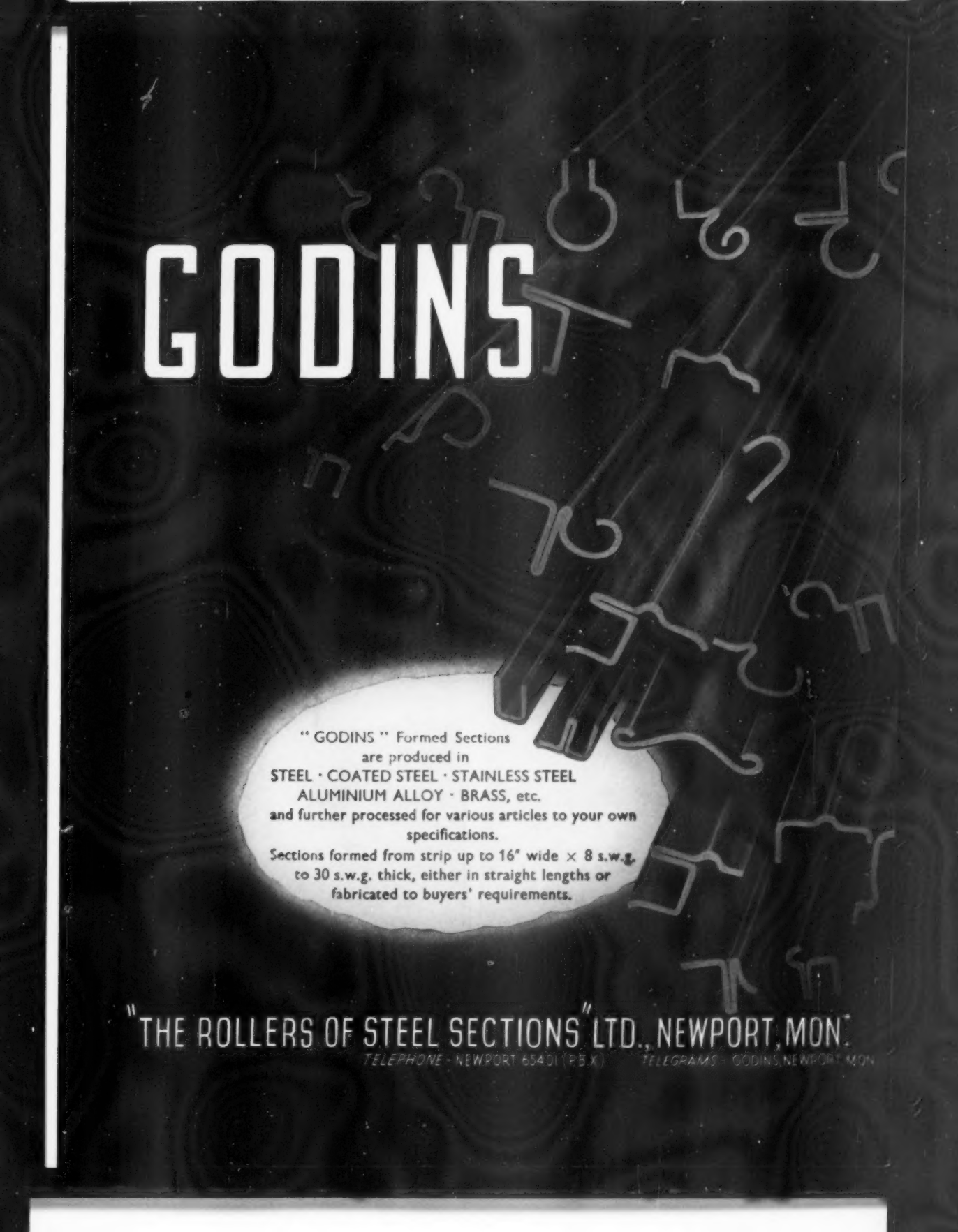
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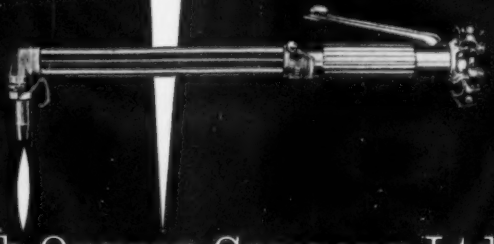

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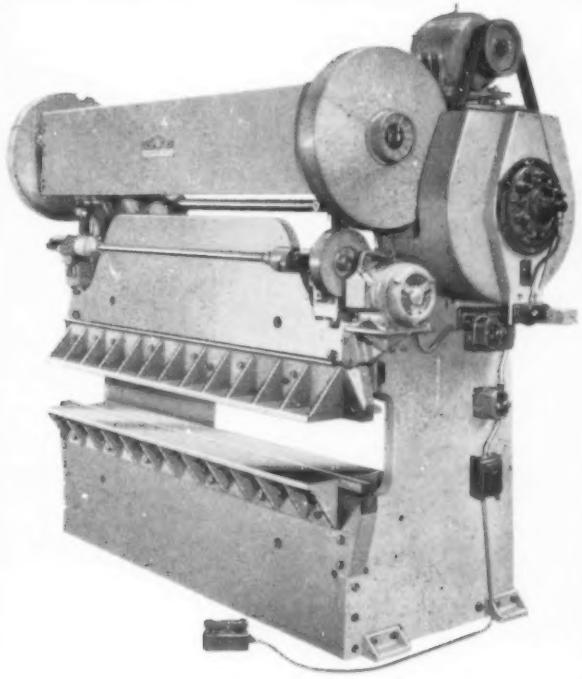

MODEL 75/8

Illustrated is Model 75/8 which is fitted with Ram and Bed shoes in the form of angle brackets to present a wide die surface.

Comprehensive catalogue of all models available on request.

The standard range of RUSHWORTH Press Brakes includes machines with capacities ranging from 30 tons to 250 tons and with distances between side frames 4 ft. to 12 ft. We are, however, prepared to quote for special machines to suit customers individual requirements.

The materials used in their construction have been selected as the best and most suitable for this type of machine. Side frames, Bed and Ram are all of high tensile rolled steel plates, machined all over and they are designed to give maximum rigidity and eliminate deflection. The Table is of ample proportion and presents a surface of adequate width to permit the use of wide die shoes.

Horning extensions of various lengths are available on all models.

On machines with a capacity of 50 tons and upwards the clutch is pneumatic and is controlled by an electric foot switch, giving extremely sensitive control.

See the O.M.F. FERRALBA PRODUCTS, Stand No. 9014, Pavilion No. 9, at the 7th EUROPEAN MACHINE TOOL EXHIBITION, Brussels, Sept. 3 to 12, 1961

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Telephone: HALIFAX 81264 5

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Telephone: LONDON ROYAL 1461 (4 lines)

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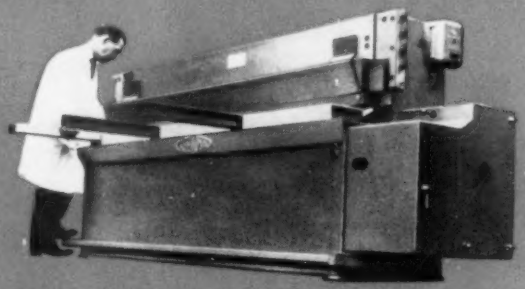
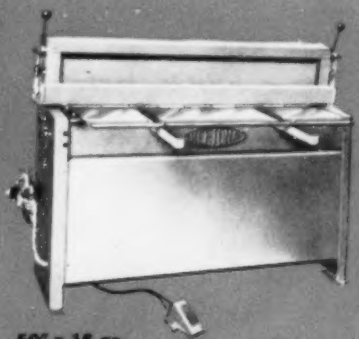
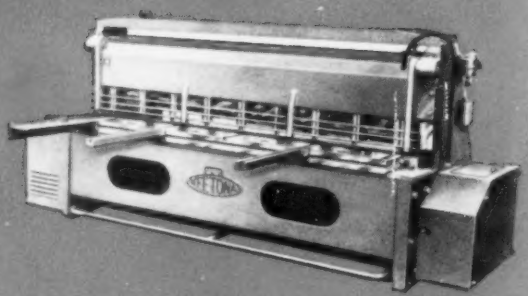


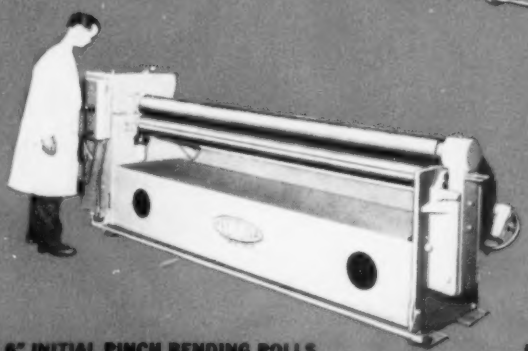
78" x 10 ga. SHEAR



50" x 16 ga.
AIR OPERATED SHEAR



96" x ¼" SHEAR
There is a full range of Keetona Shears in capacities from 40" x 18 ga. to 120" x ¼"



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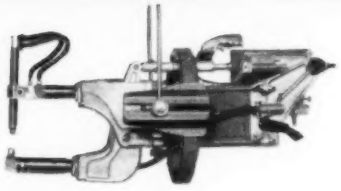

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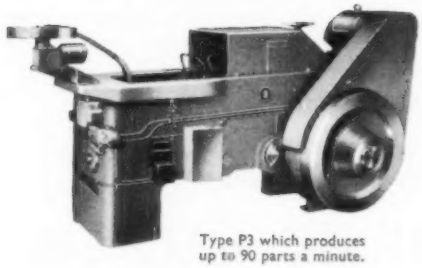

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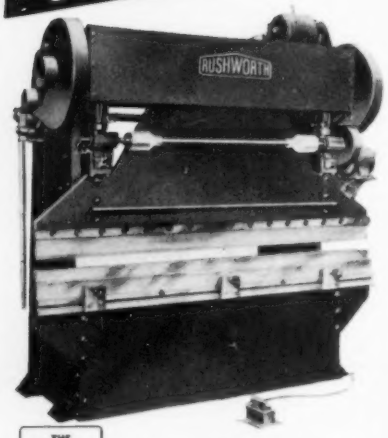

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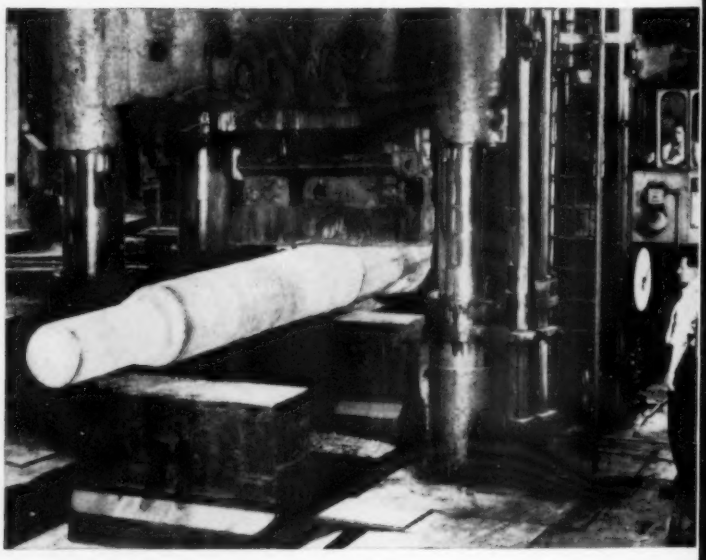

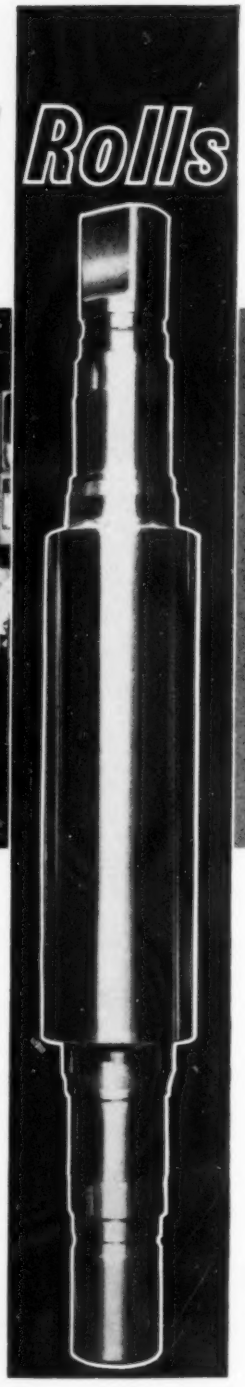

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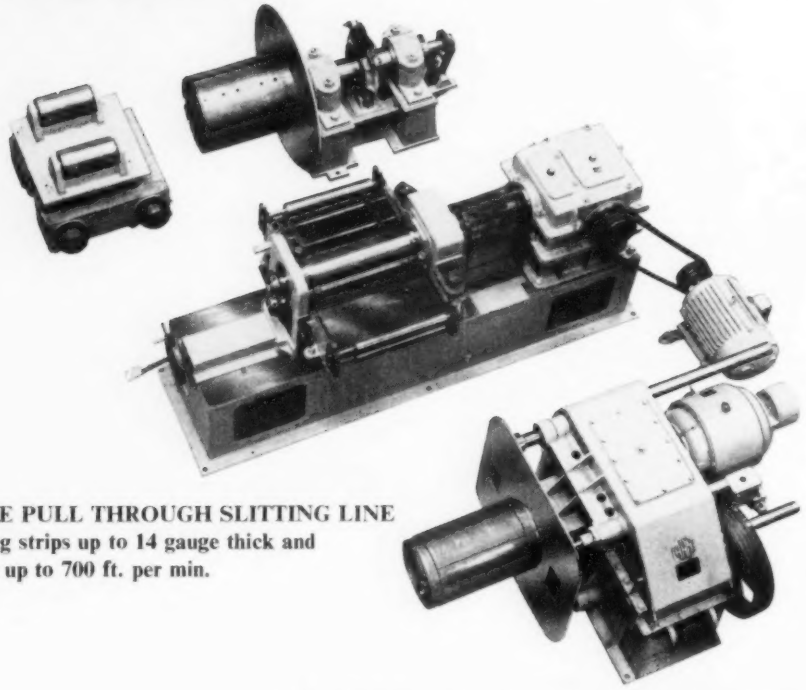

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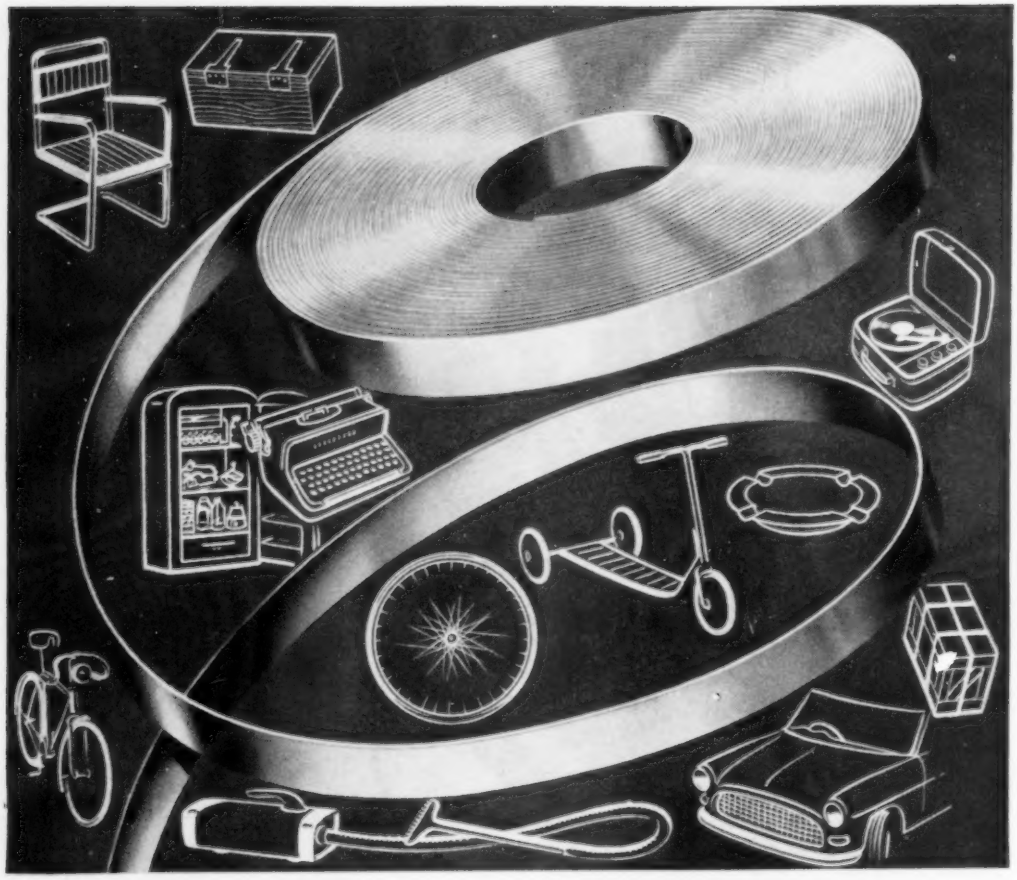

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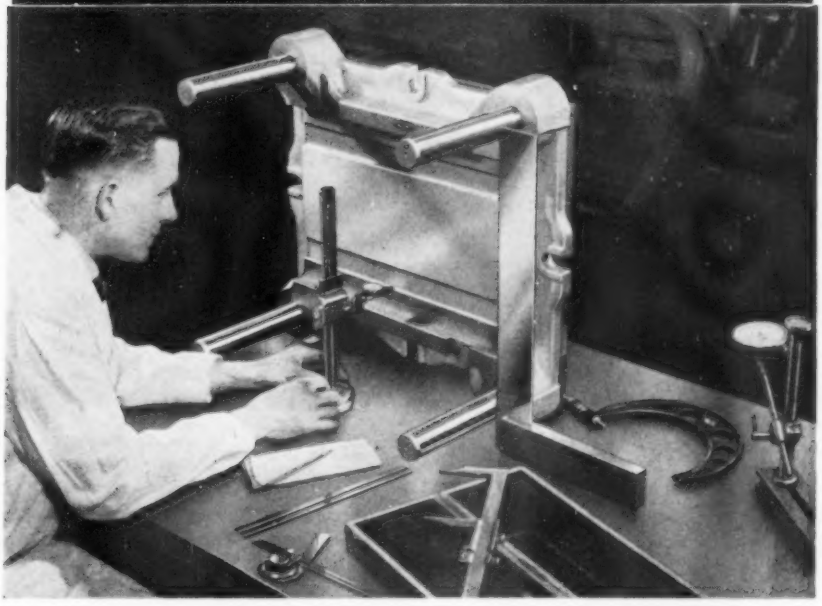

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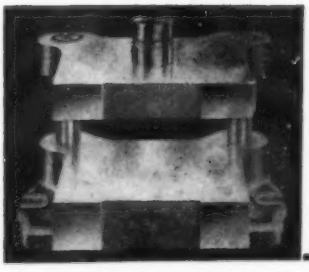

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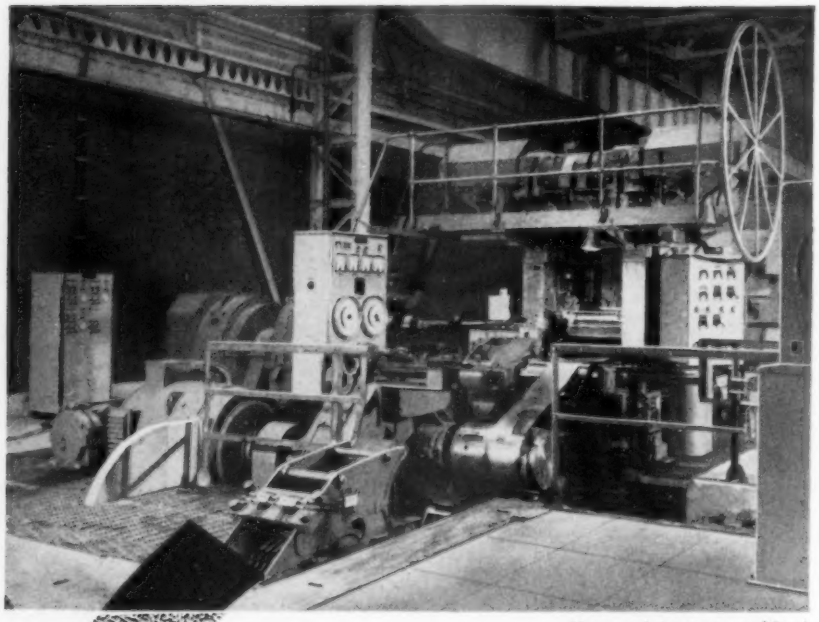

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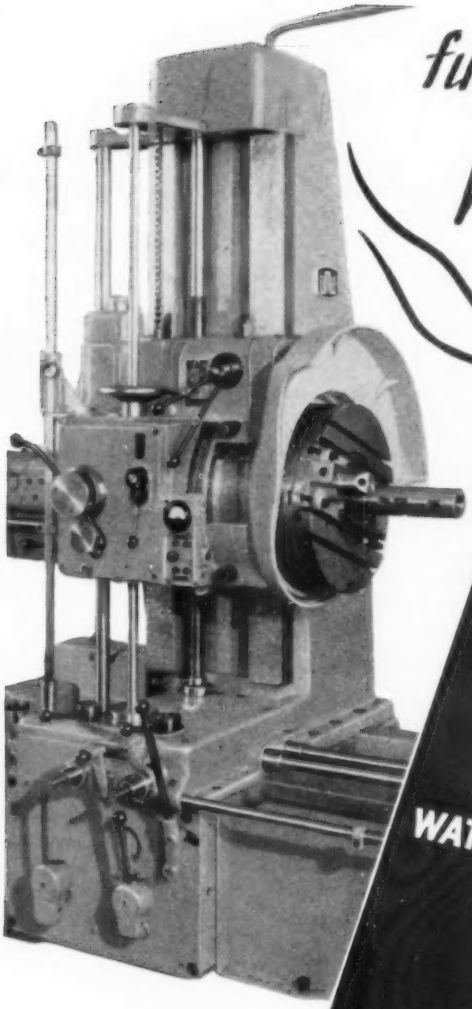

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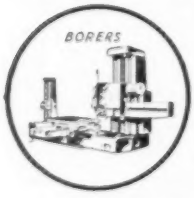

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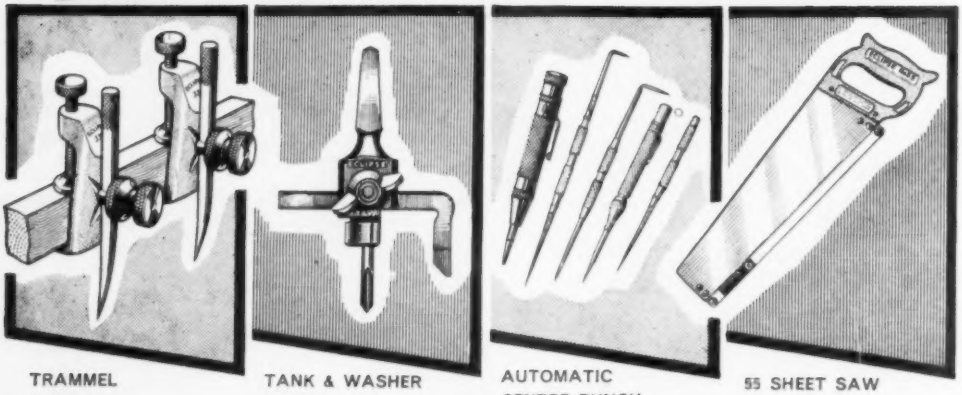

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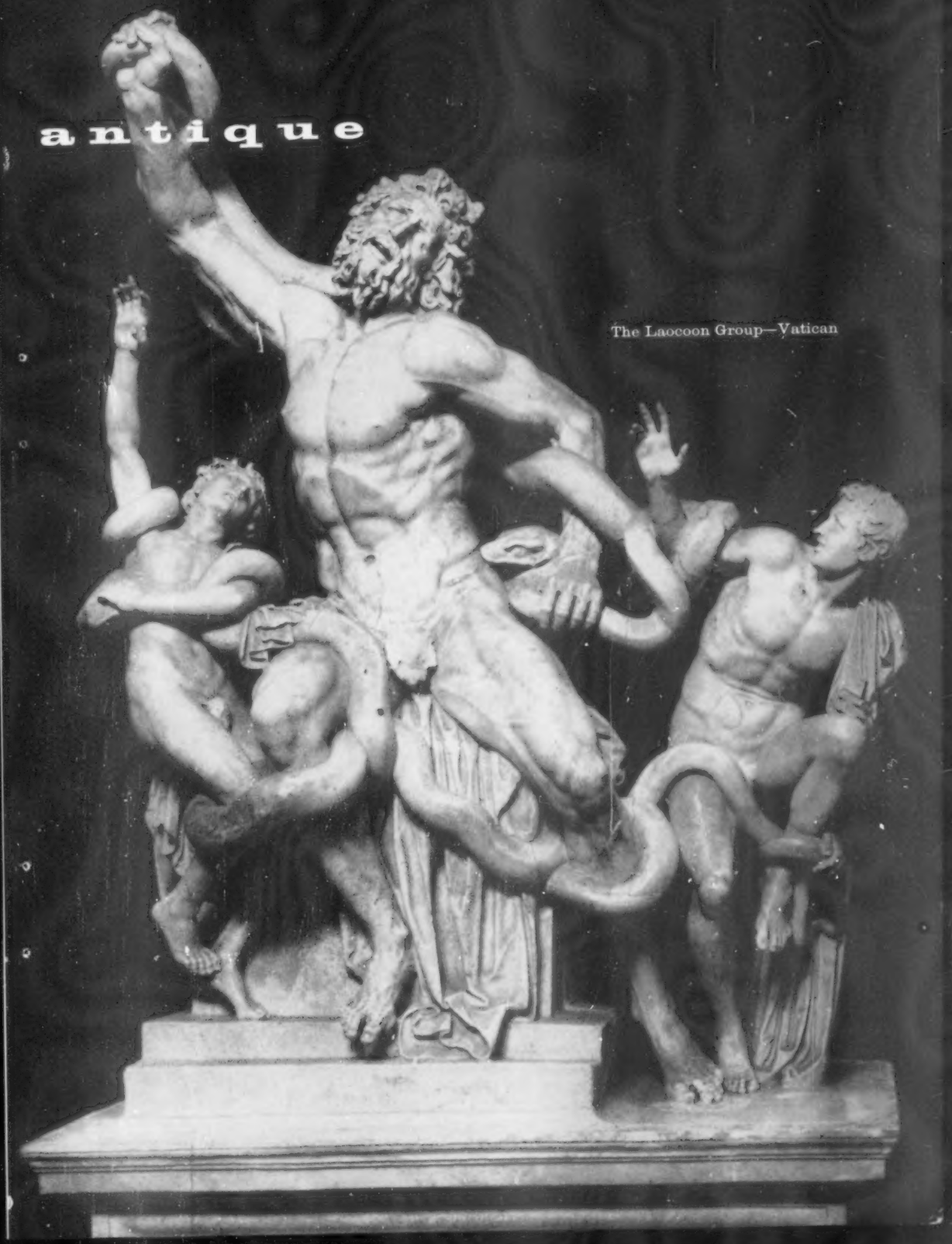

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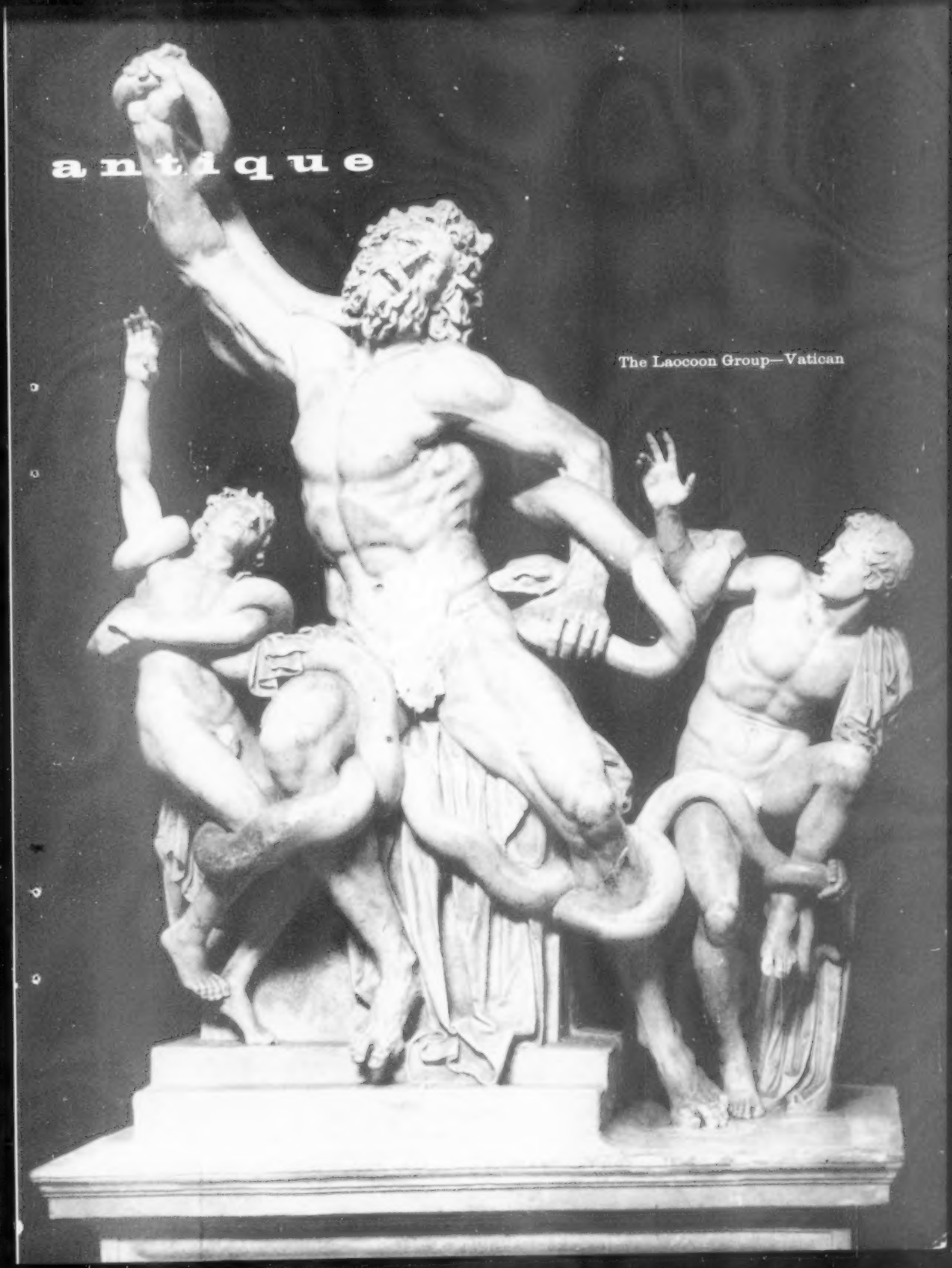

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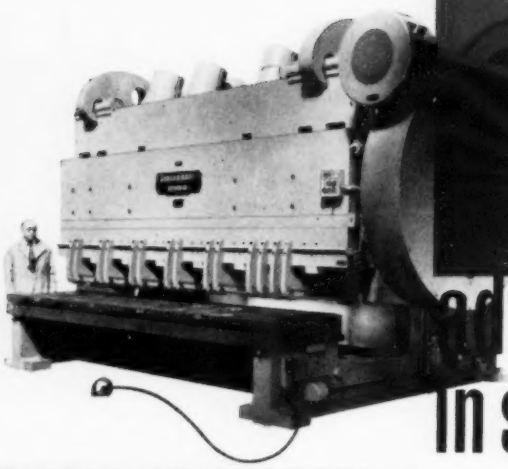

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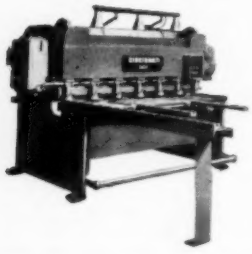

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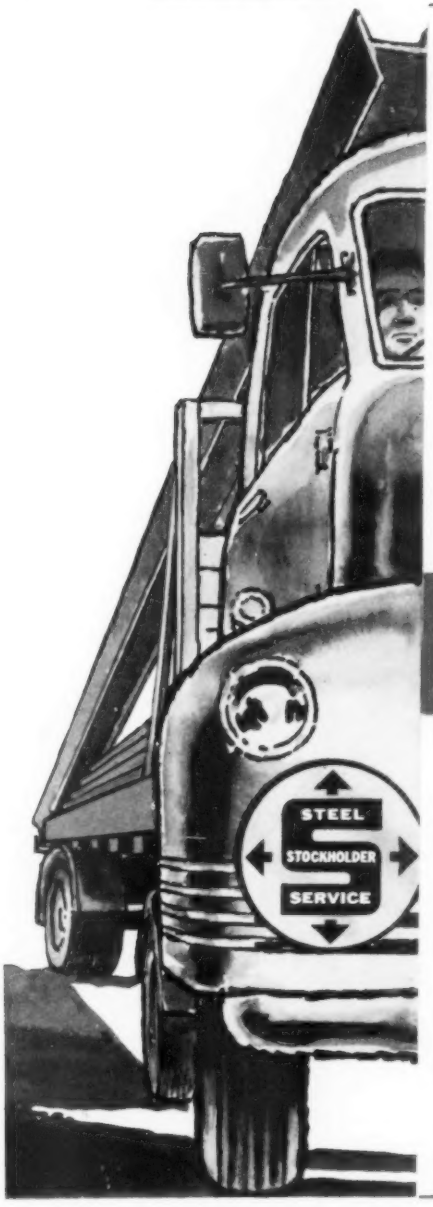

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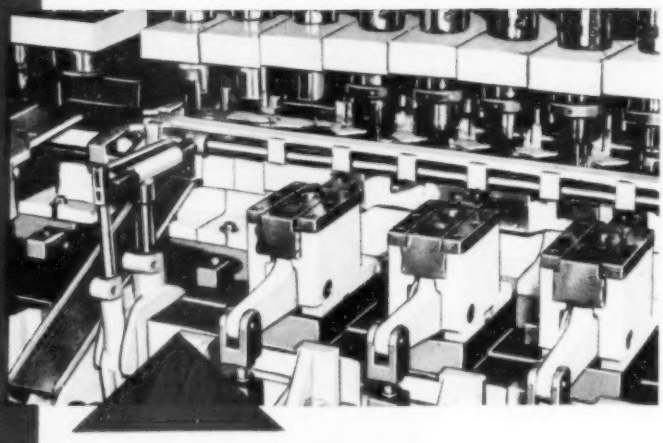

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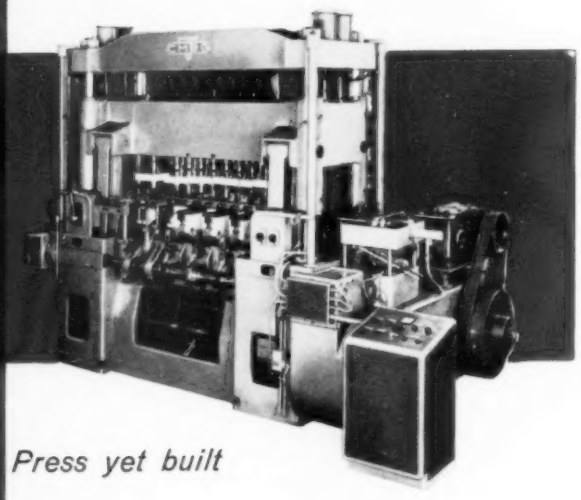

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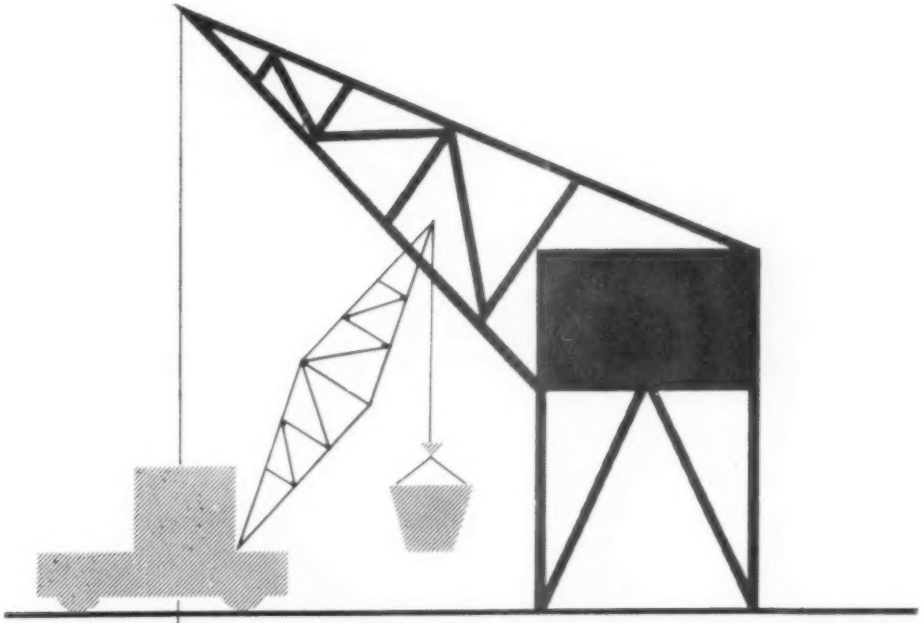

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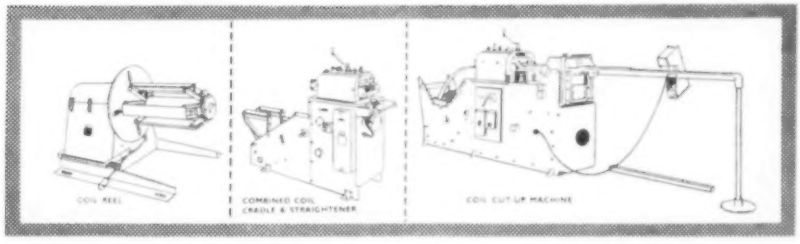

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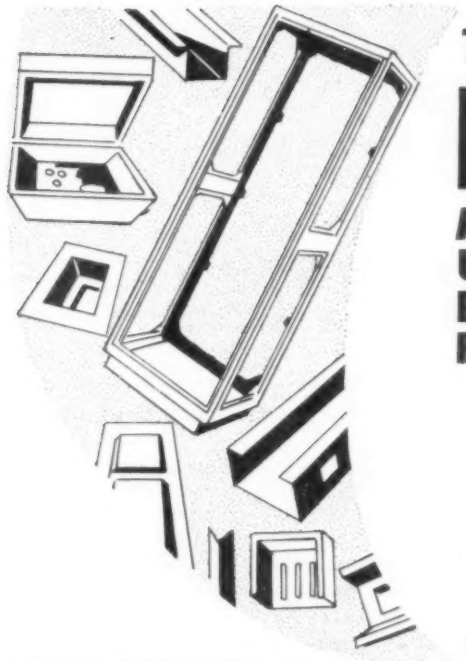

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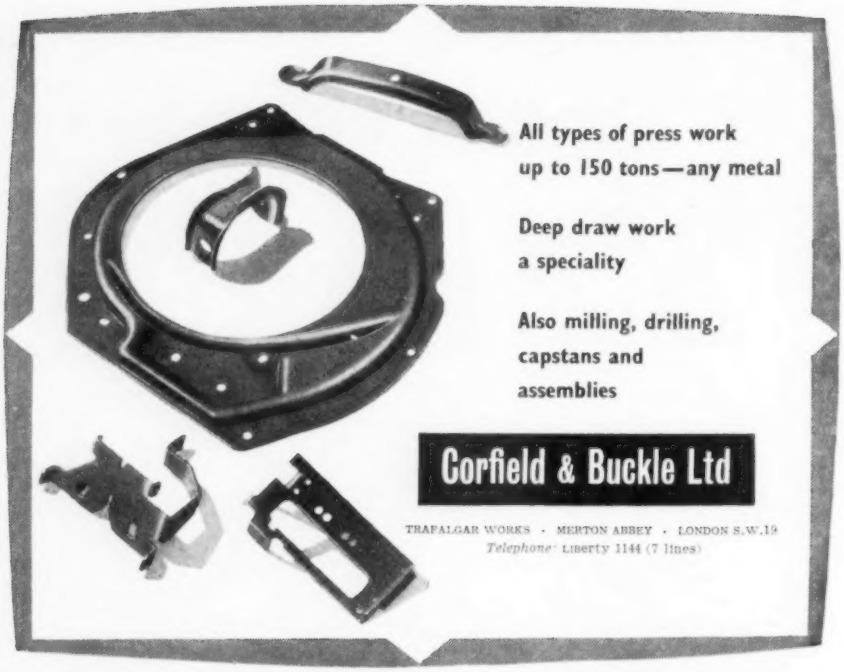
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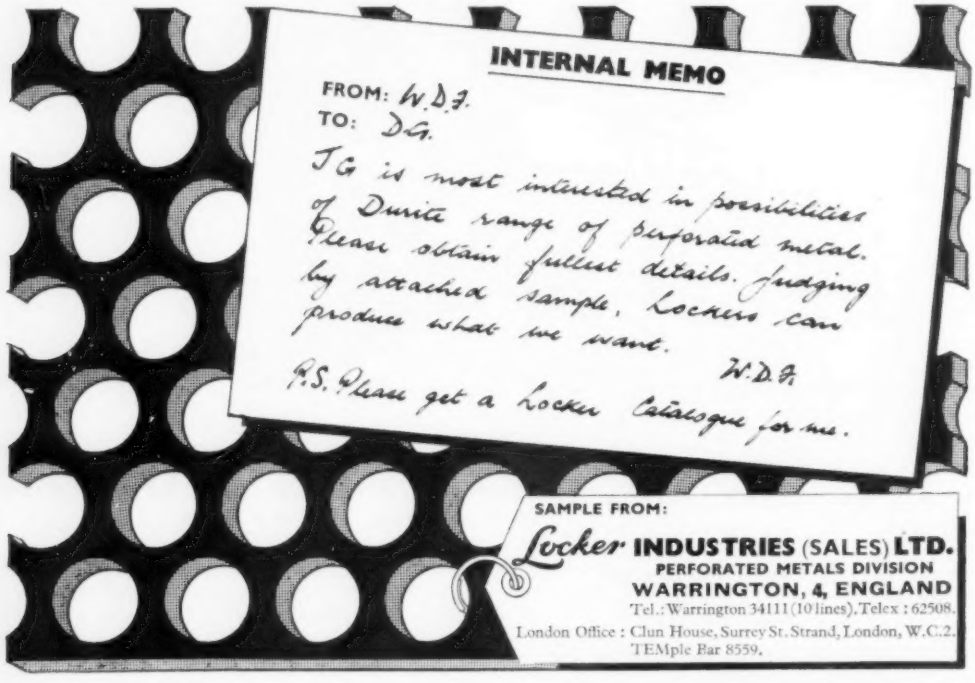
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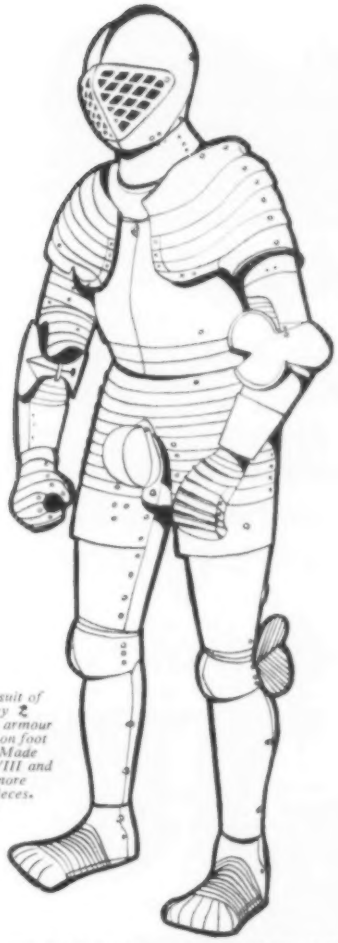

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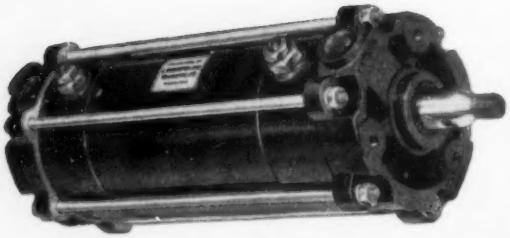

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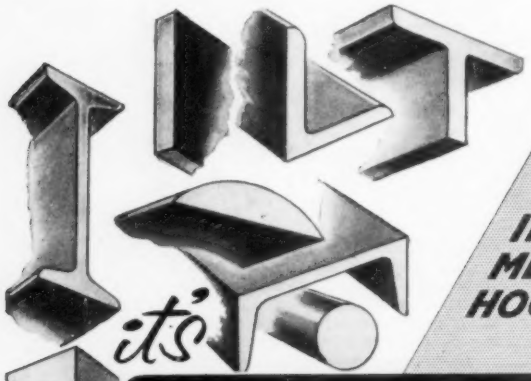

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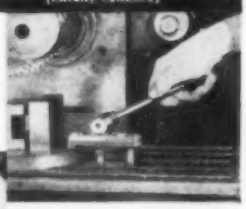
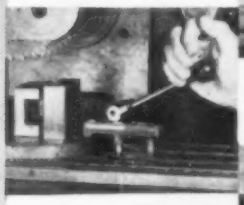
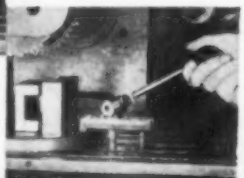




2 Operator pushes handle to rotate the cam unit for final screw clamping to increase pressure.



3 Easily detachable handle is being removed, leaving job firmly clamped and allowing cutters to pass over work.

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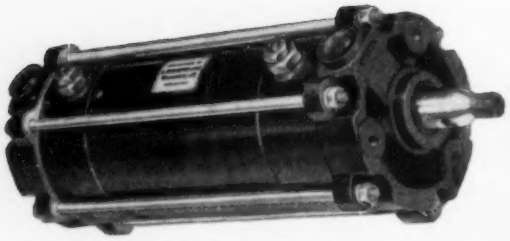

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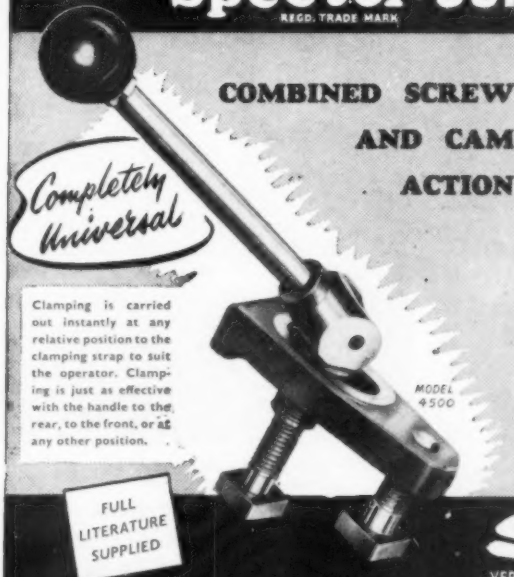

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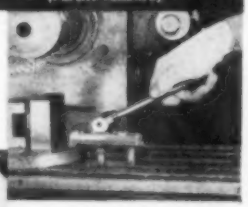

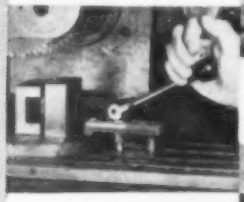

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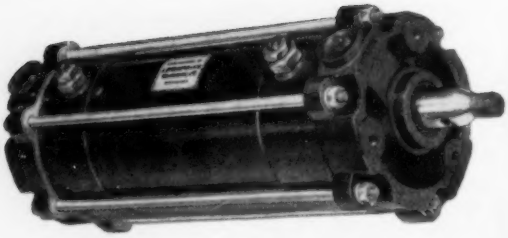

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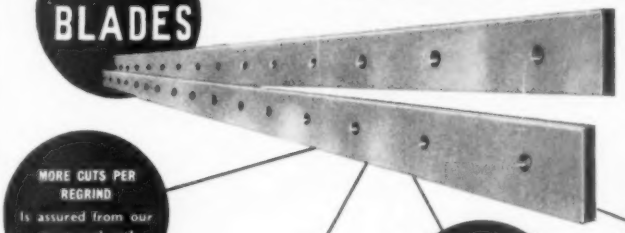

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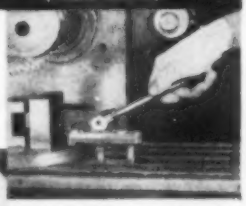
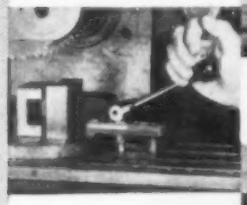
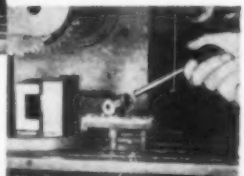
MODEL 4500

1 Illustration alongside shows set-up for a milling operation. Clamp handle is depressed to clamp down the work.





2 Operator pushes handle to rotate the cam unit for final screw clamping to increase pressure.



3 Easily detachable handle is being removed, leaving job firmly clamped and allowing cutters to pass over work.

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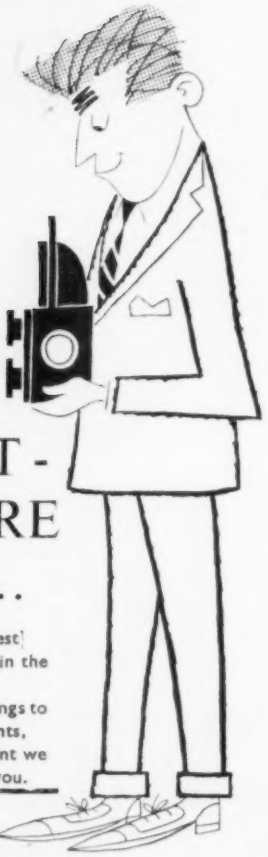

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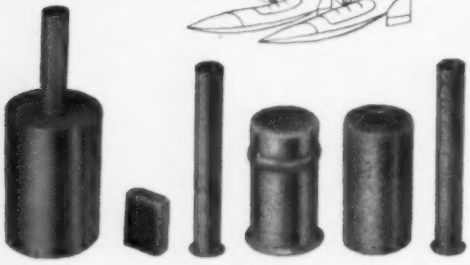

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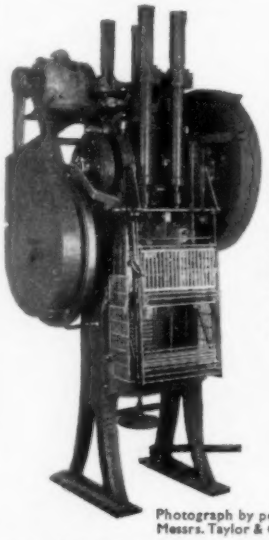

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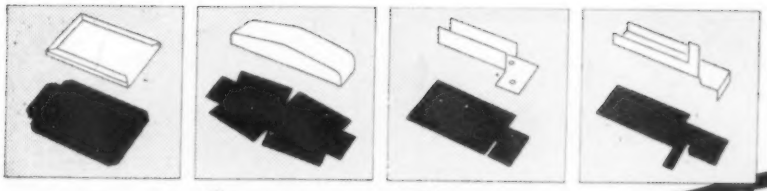

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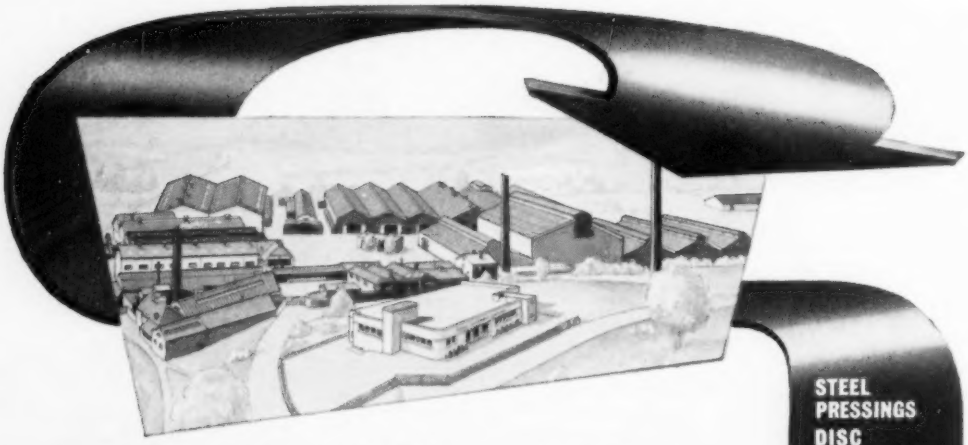

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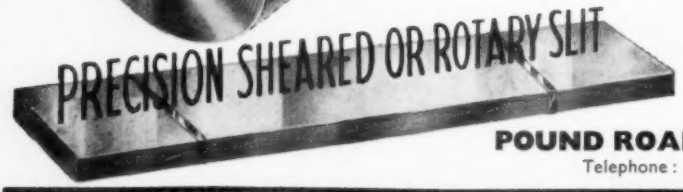

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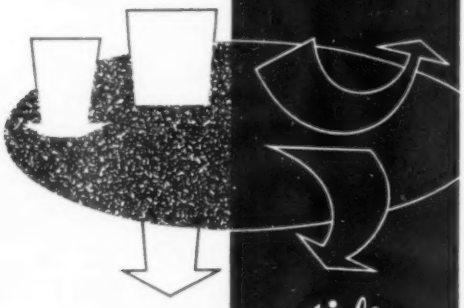

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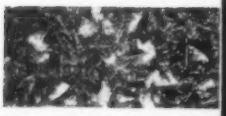

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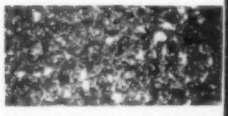

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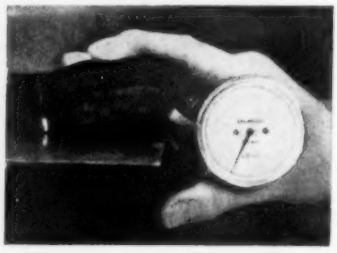

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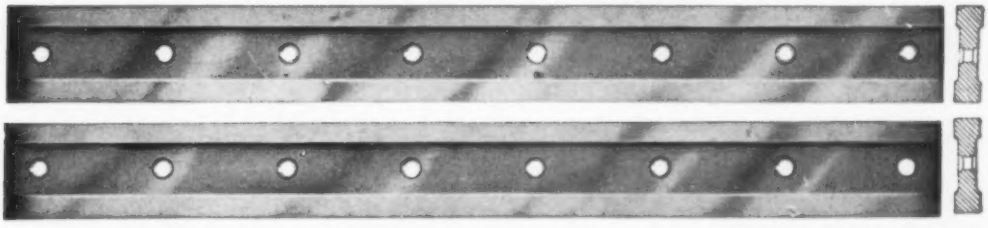

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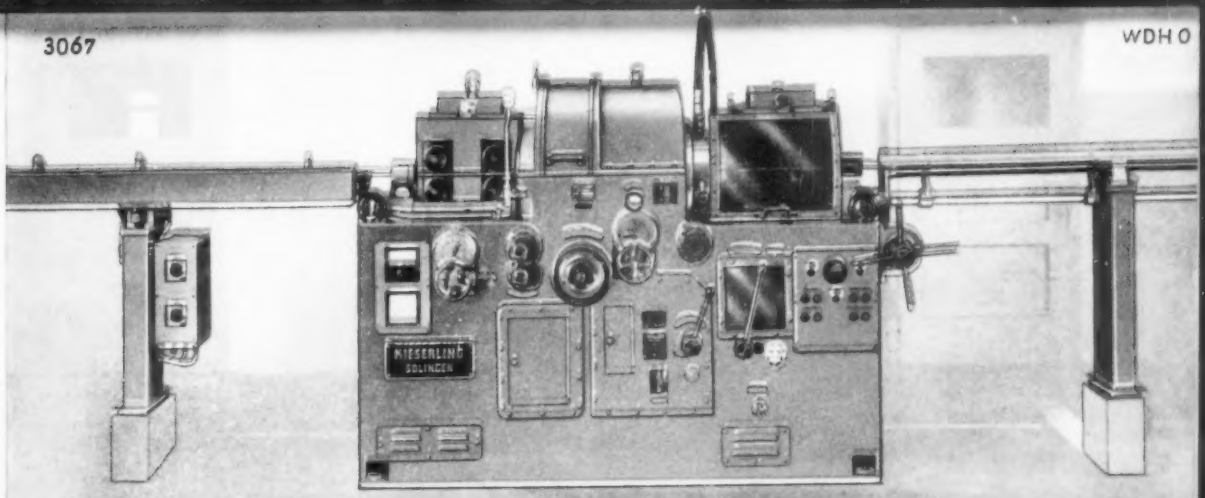

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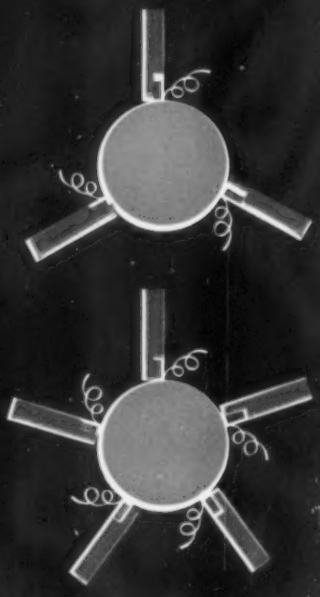

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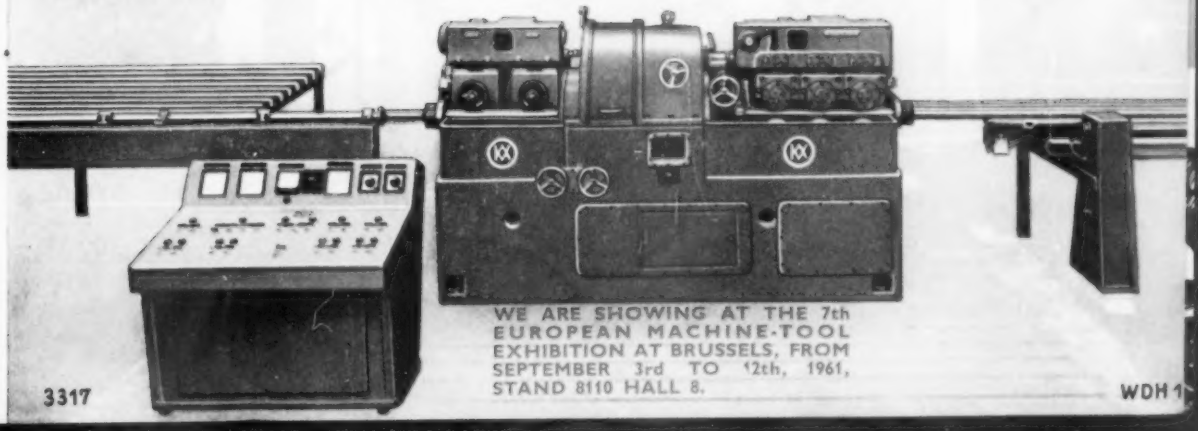

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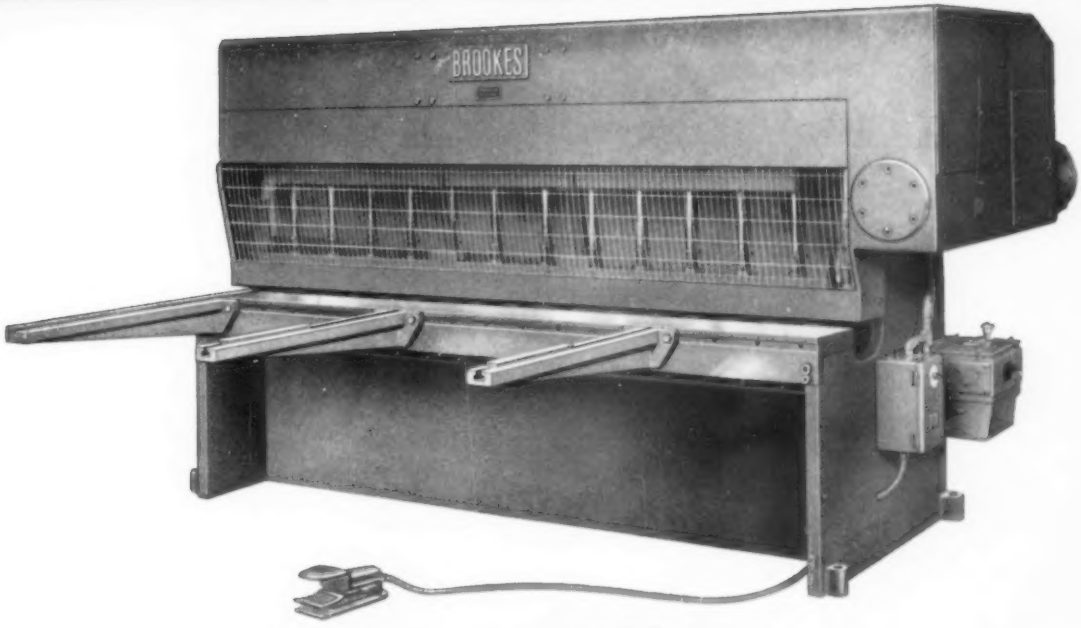

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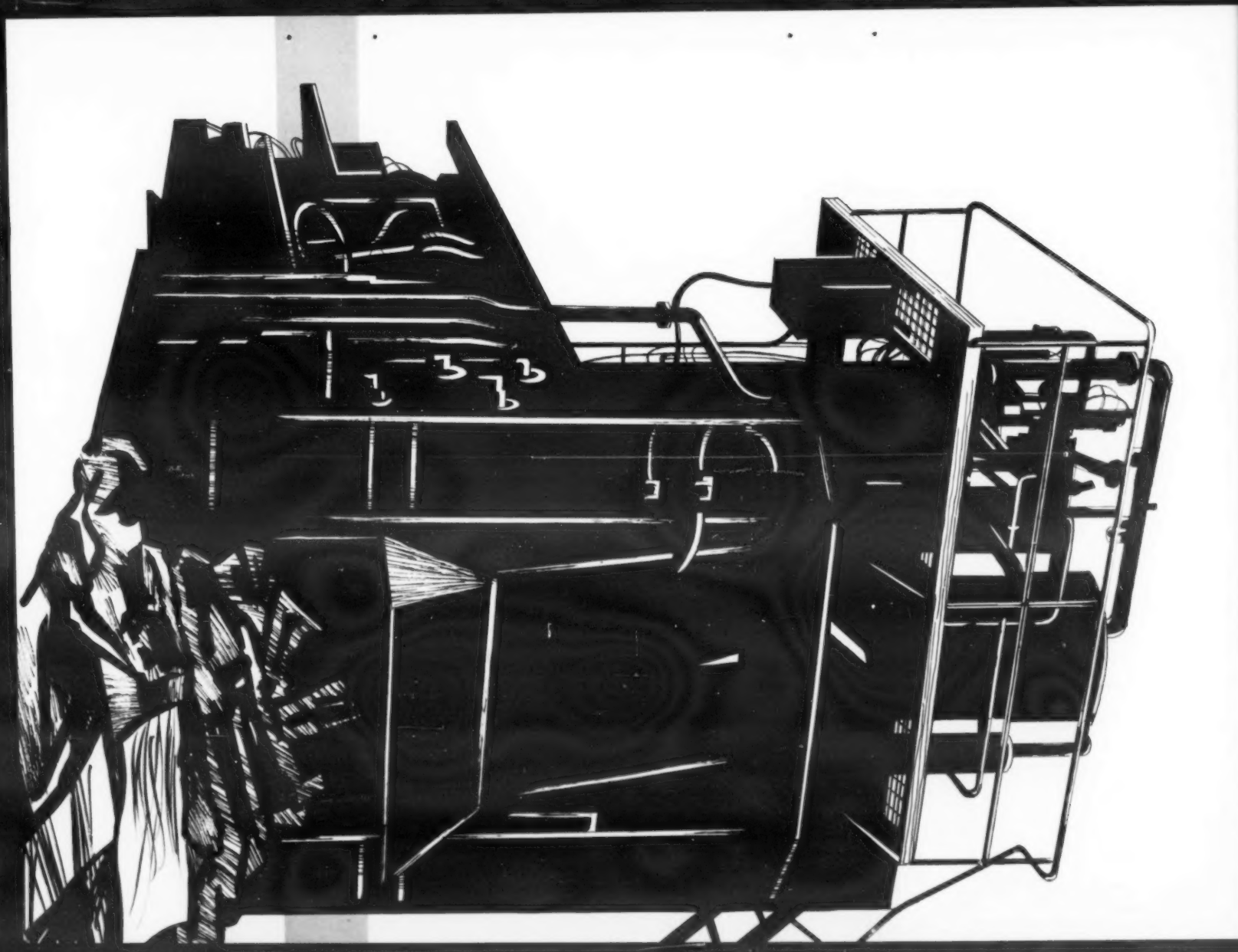

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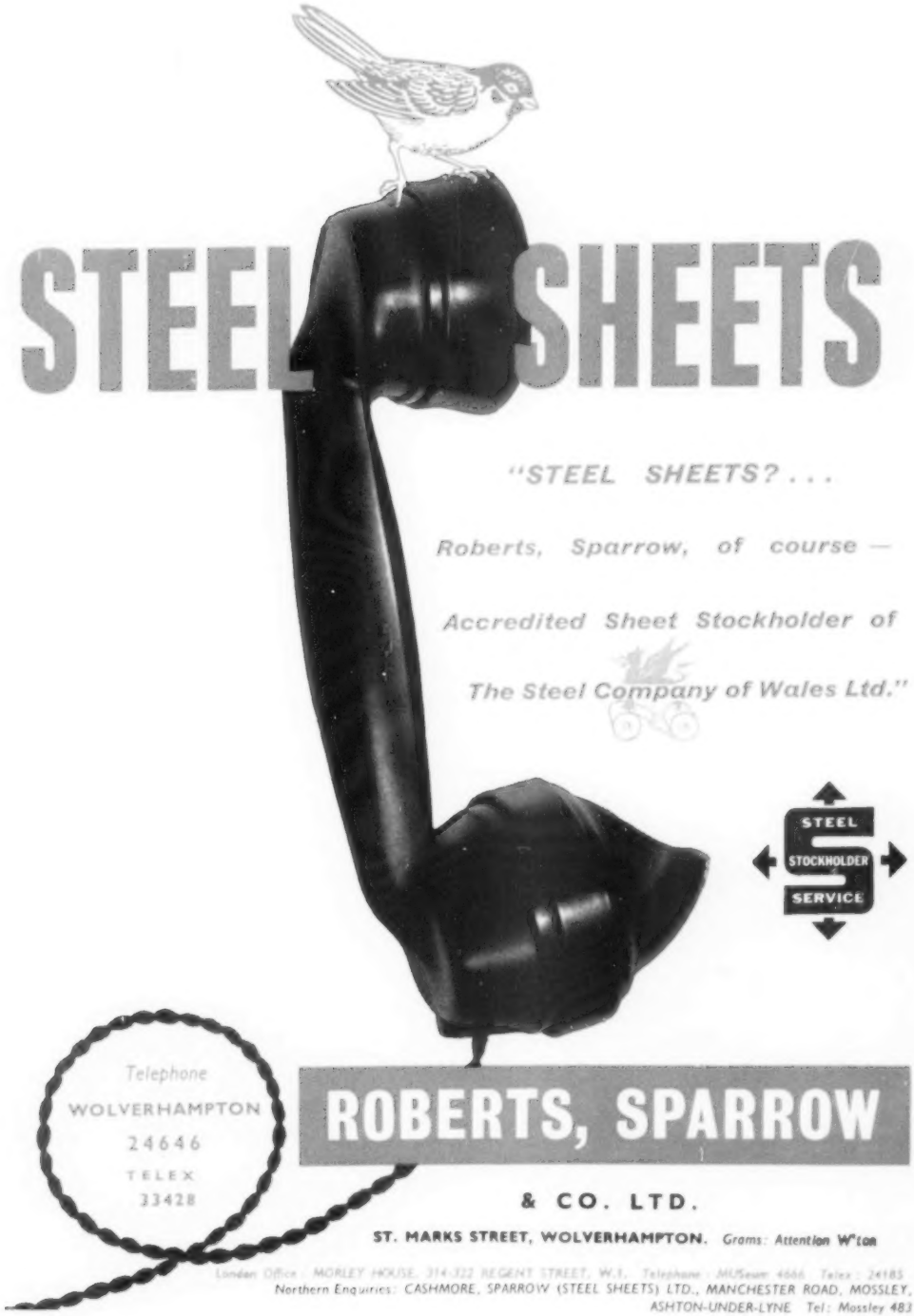

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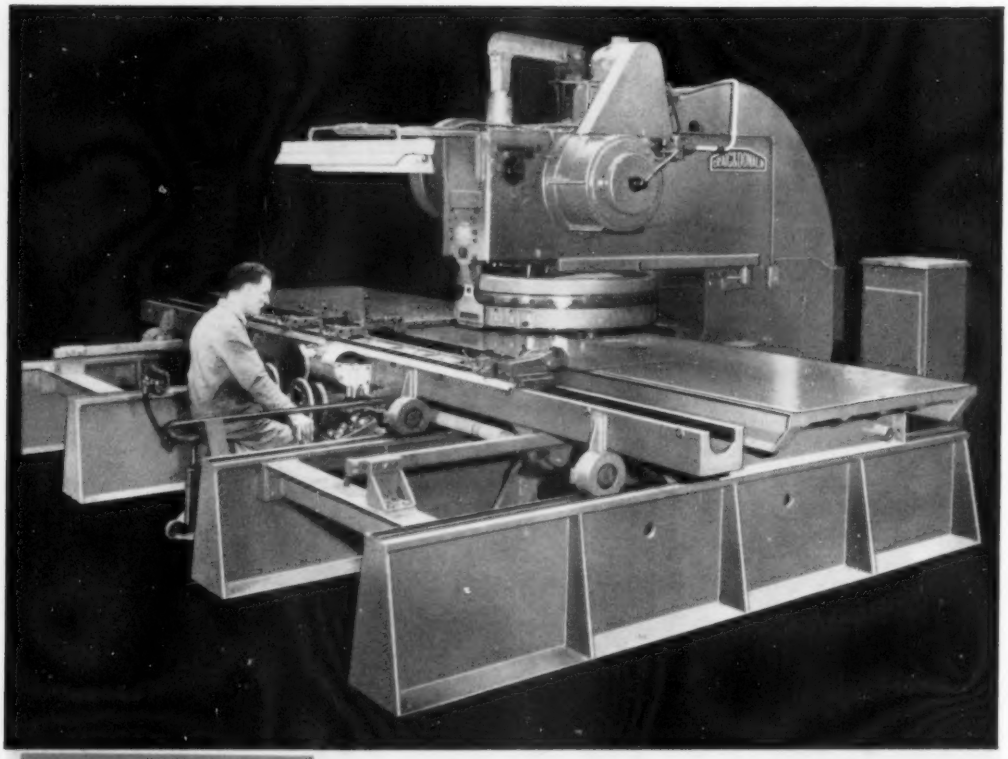

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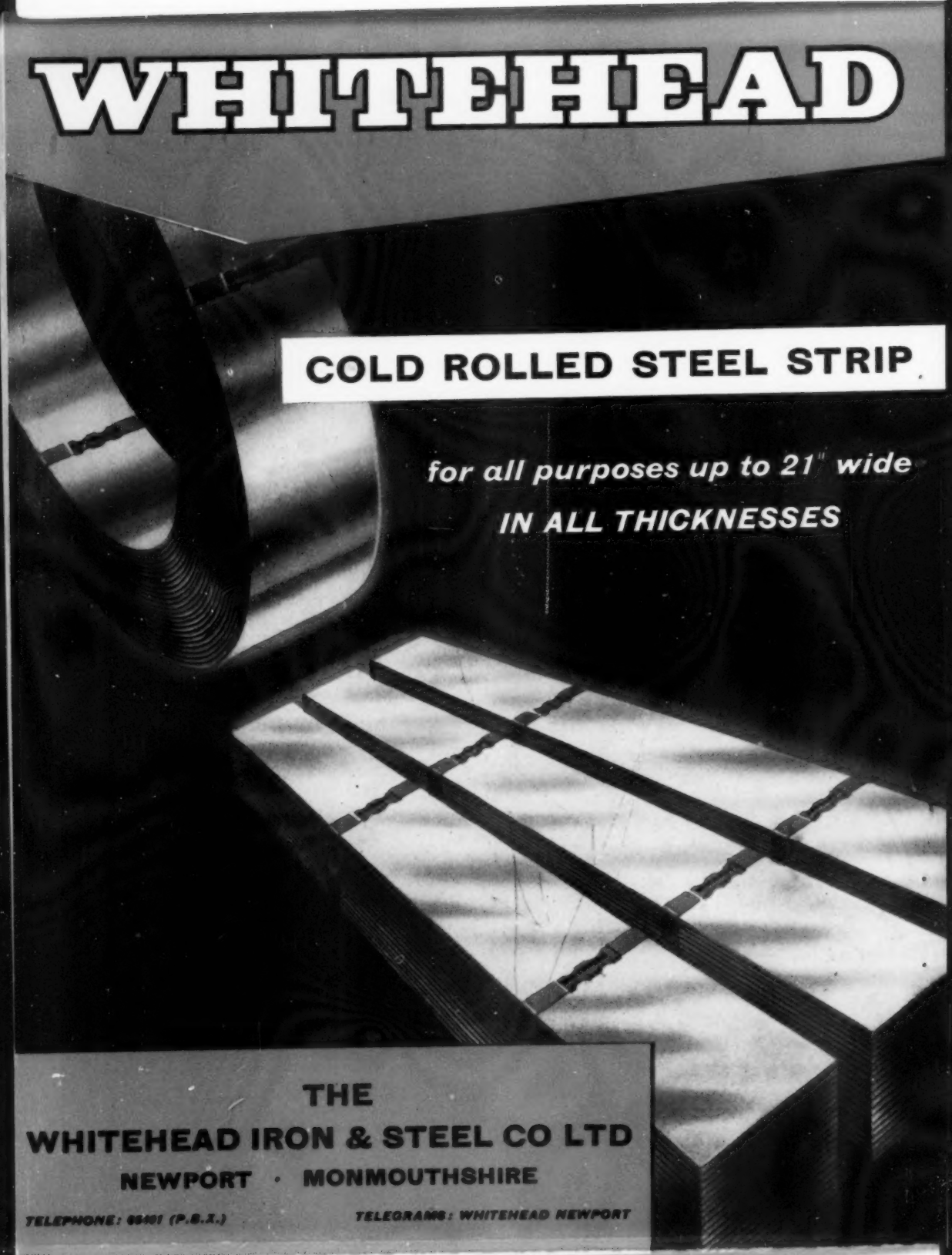

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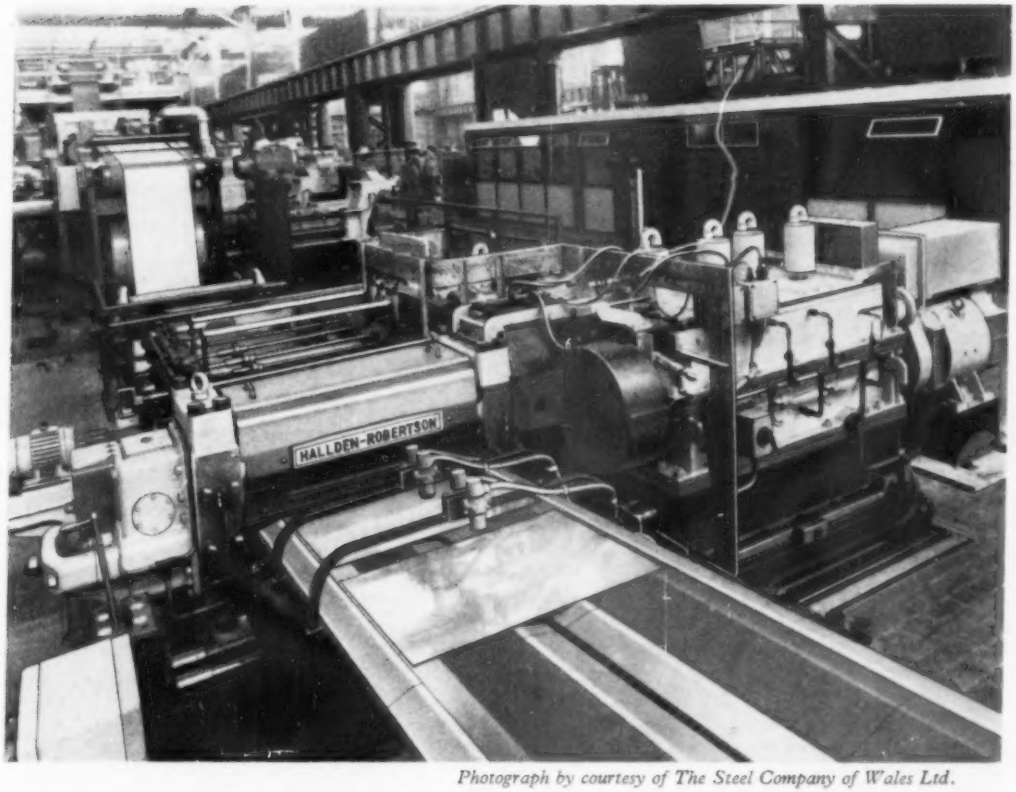
ARE INCLUDED IN THE THREE ELECTROLYTIC TINNING LINES INSTALLED AT THE VELINDRE WORKS OF THE STEEL COMPANY OF WALES LTD.



Photograph by courtesy of The Steel Company of Wales Ltd.

The three Cut-up Lines fitted with this Hallden design machine are capable of dealing with all tin-plate gauges and sheet sizes up to a rate of 428 sheets per minute each.

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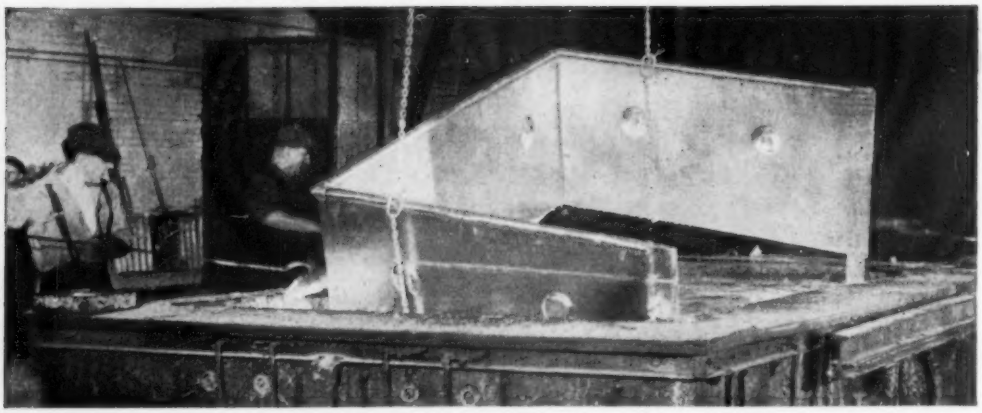

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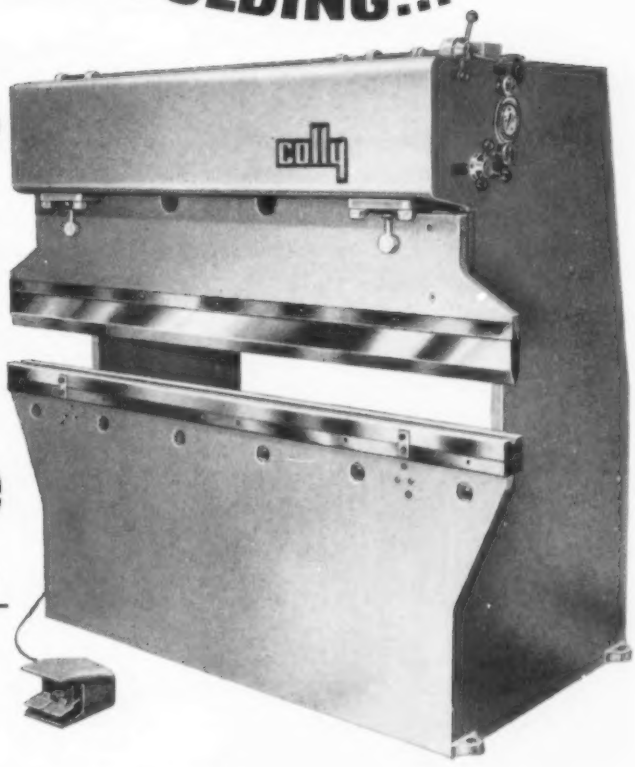

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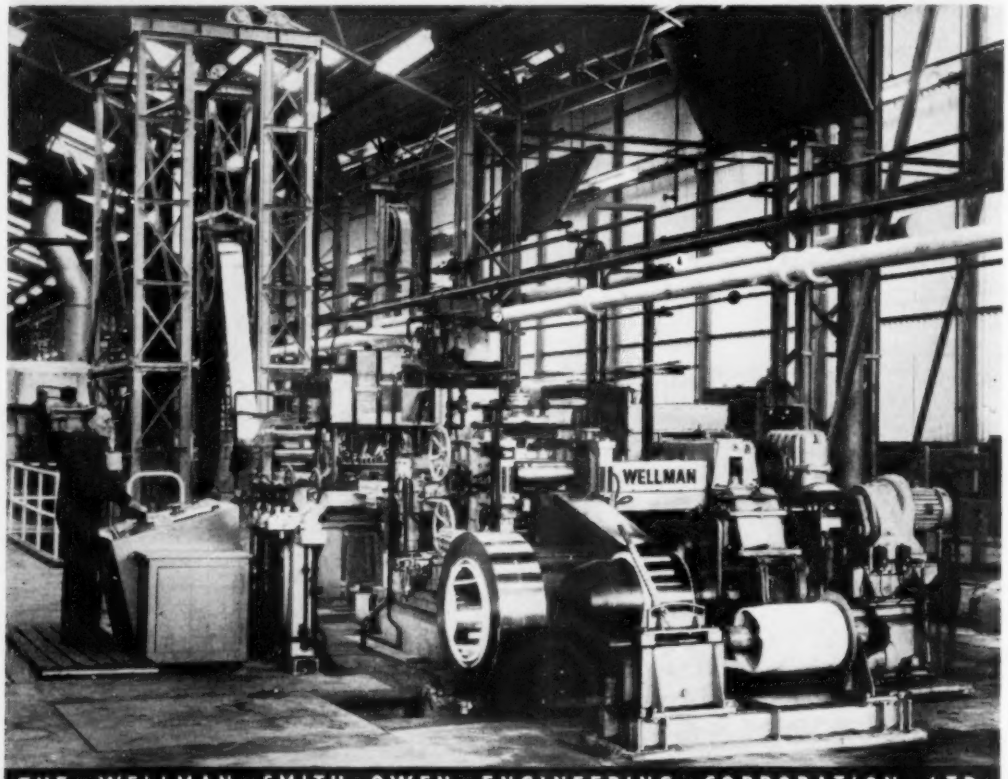

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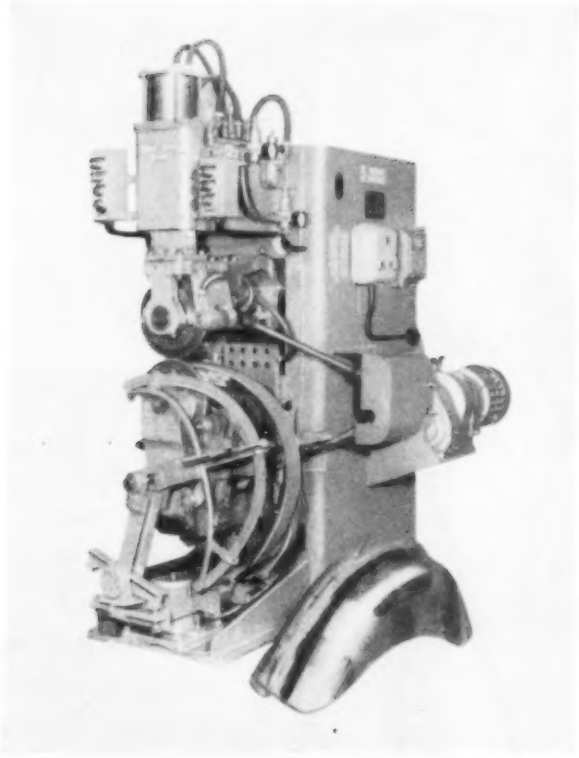

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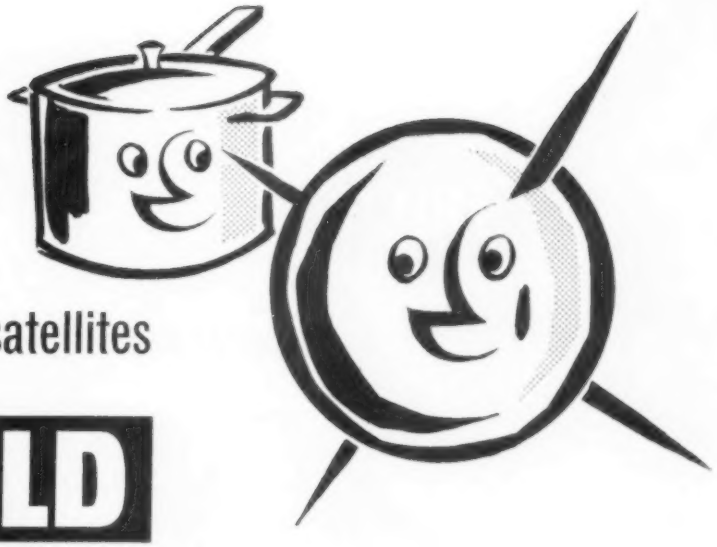

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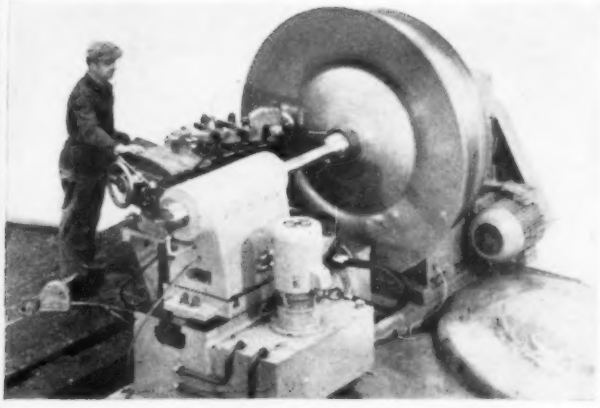

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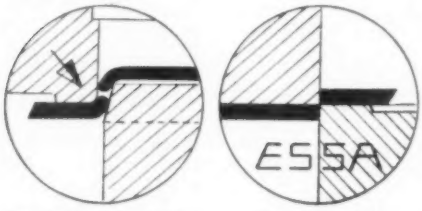

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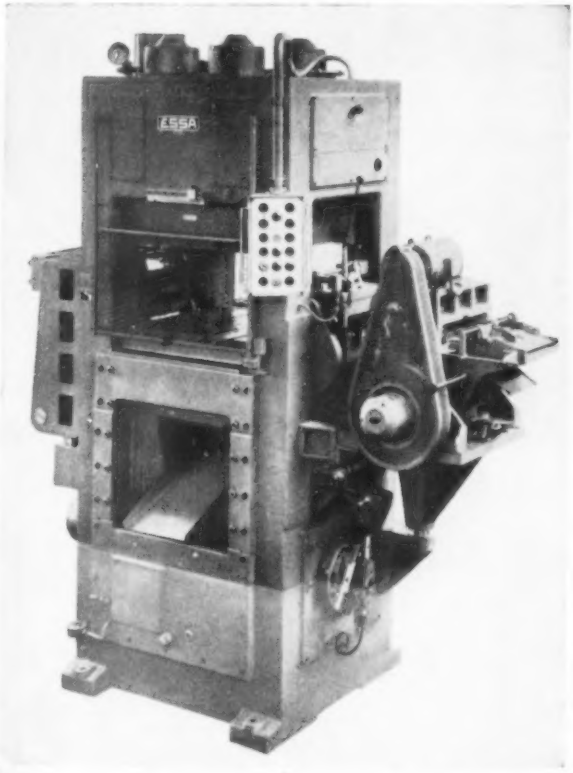

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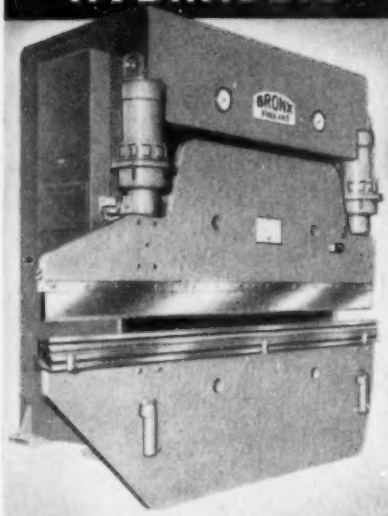

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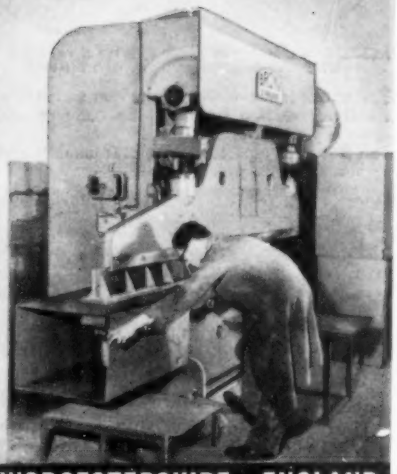

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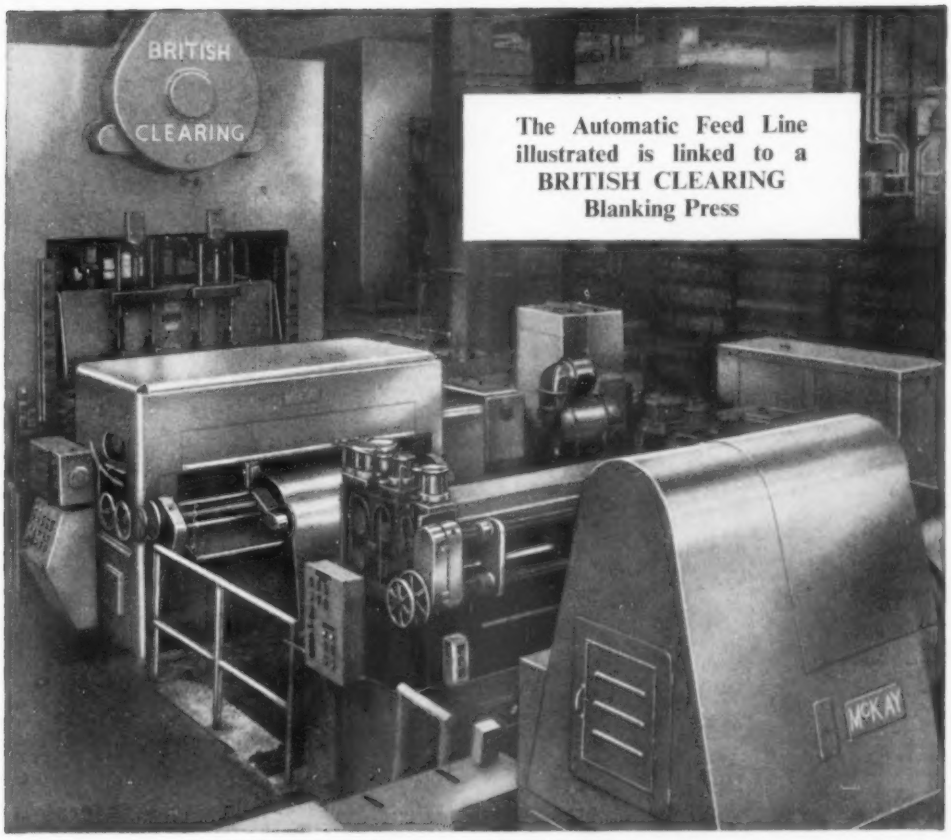

The Automatic Feed Line illustrated is linked to a BRITISH CLEARING Blanking Press

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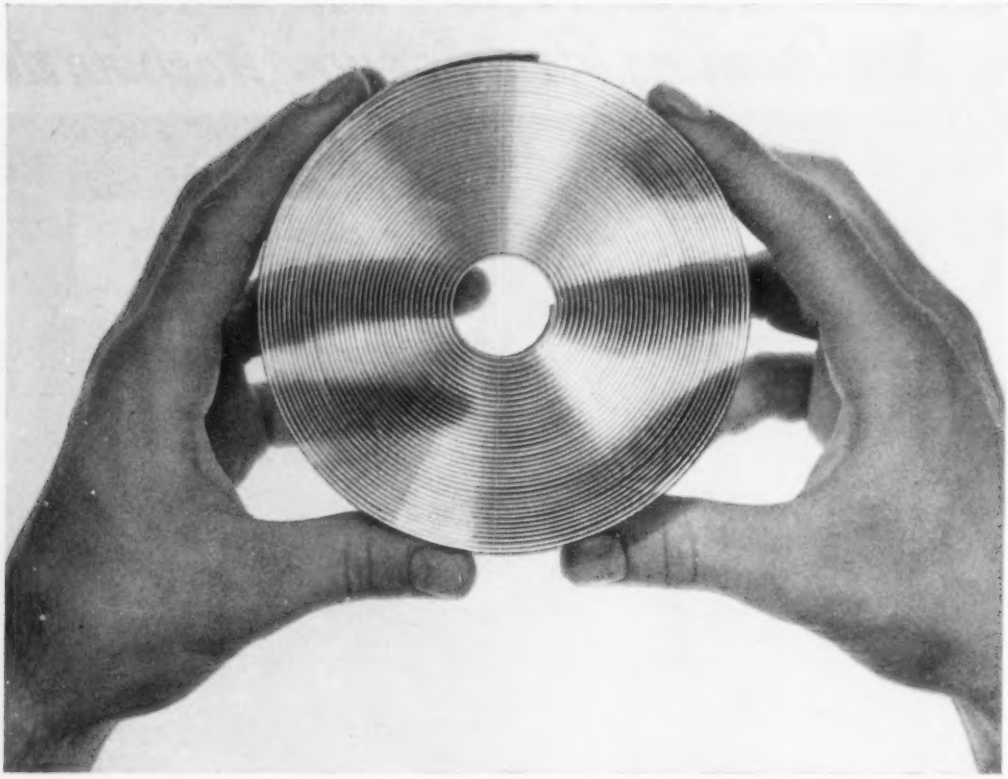

This steel coil has been wound leaving air spaces between each lamination—the principle of the OPEN COIL PROCESS. The gases can now reach the complete surface of the steel in the coil, making gas alloying possible i.e.

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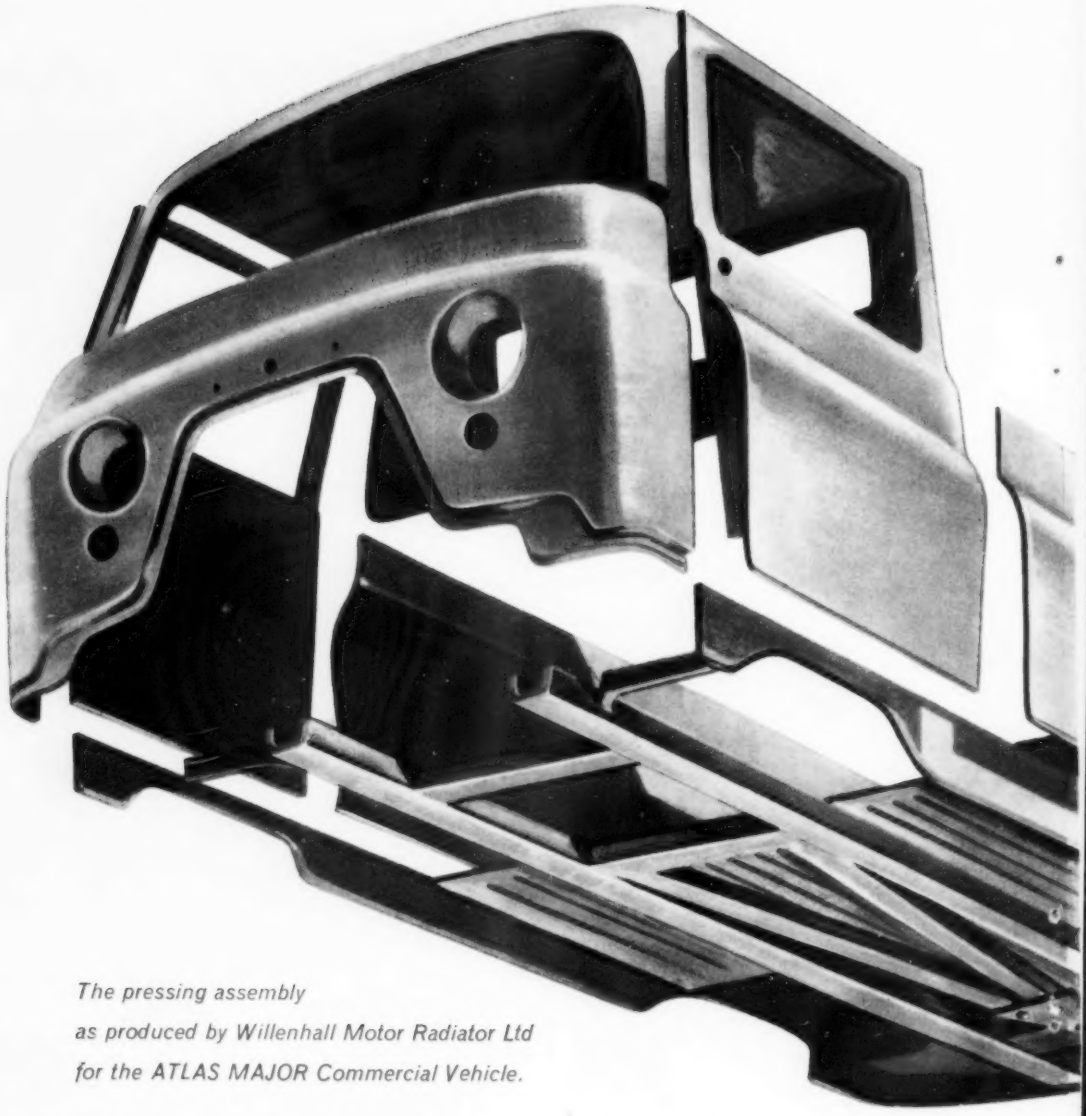

The pressing assembly
as produced by Willenhall Motor Radiator Ltd
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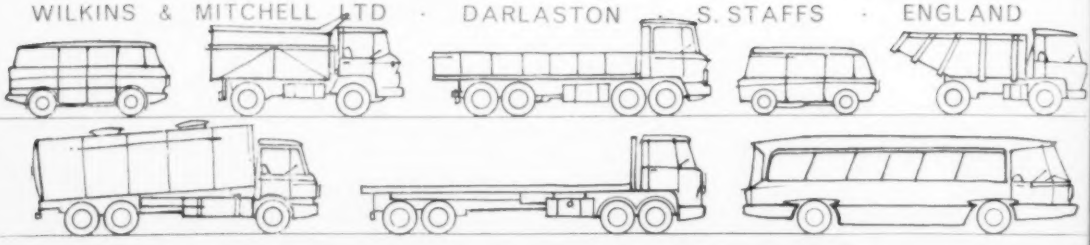
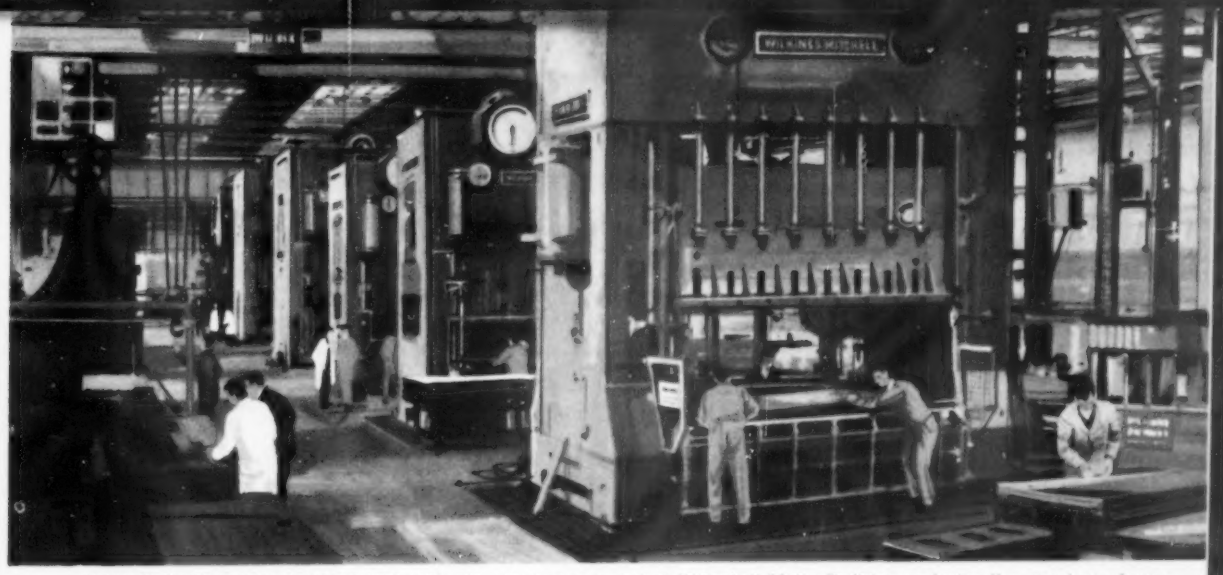
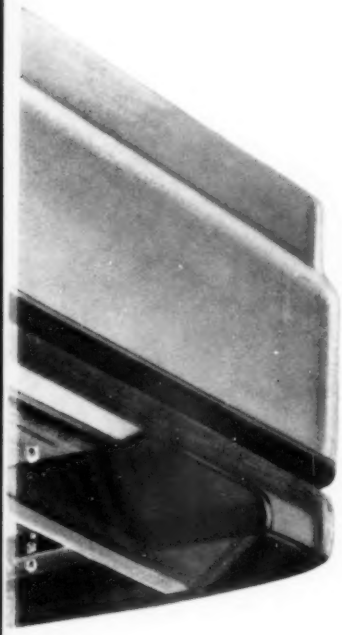




WILKINS & MITCHELL PRESSES (350, 400, 600, 800 tons capacity) at Willenhall Motor Radiator producing the pressings shown.



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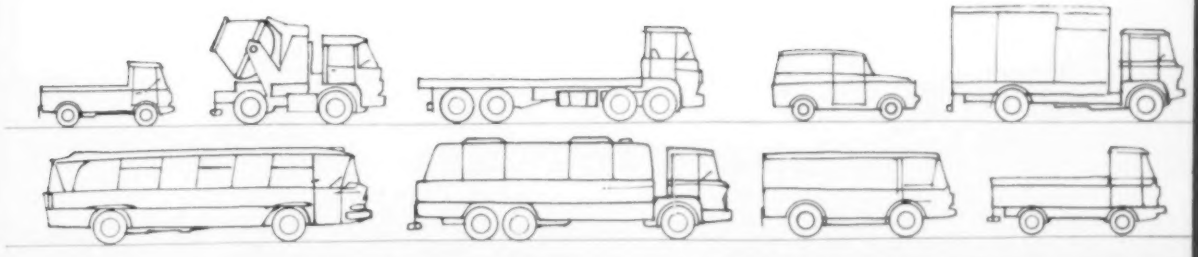

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One of the features of the changing skyline of the towns and cities is the rapidly increasing use of vitreous-enamelled panels on the exteriors of new buildings. This article gives information on factors influencing the design of such panels and describes production procedures at the Tooting, London, works of Stewart and Gray Ltd. The article is illustrated in colour and black-and-white, and the illustrations include examples of the many buildings clad in panels produced by the company.

Use of Galvanized Strip in Automobile Manufacture in the U.S.A. 631
By K. P. Scott and M. H. Davies
The recent trend towards unitized body construction for American motor cars has been accompanied by a demand for materials with improved corrosion resistance and large tonnages of zinc-coated steels, the preferred materials, are now being used.
Considerable interest in this development has been shown in the U.K. and this report, which has been made available by the Zinc Development Association as a result of a visit paid to the U.S.A. by the authors, is intended to give an account of current practice in the U.S.A. which, it is hoped, will be of assistance to British industry.

Determination of the Deep-drawing Capacity of Aluminium and its Alloys 637
By Robert Chopin
The author, who is director of the Centre Technique de l'Aluminium, Paris, sets out to show that it is apparently impossible to determine the deep-drawing capacity of the various aluminium alloys by the customary properties and tests even in the most simple case of the cylinder.
He considers that among the current methods of investigation only full-scale practical tests, made on several diameters and thicknesses will make it possible to plot curves, which, by interpolation, will provide useful information for deep drawers.

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This paper was presented to a joint meeting of the International Deep Drawing Research Group and the Société Française de Métallurgie.

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Quantitative Assessment of Deep-drawing and Stretch-forming Qualities—1 649
By J. G. Wright, B.Sc., Ph.D., A.I.M., A.C.T.(Birm.)
This is the first instalment of three which constitute a survey of the subject and based on two lectures given by the author in a special course on "The Metallurgy of Deep Drawing and Pressing" held at the Department of Metallurgy, Birmingham College of Advanced Technology. In this instalment Dr. Wright, who is Reader in Industrial Metallurgy at the College, first elucidates the various forming processes and then deals with tests of general metallurgical quality, non-simulative quantitative tests, simulative tests and cupping tests.

Quality Control in the Production of Steel Sheet for Deep Drawing and Pressing 659
By W. O. Thomas, A.I.M.
Because of the rapid growth of the motor-car industry during the past 30 years there has been an increasing demand for cold-reduced sheets, a demand that has been met by the rapid development of new strip-mill capacity. The shape of the modern automobile necessitates presses of greater power and speed producing deeper and more intricate pressings, which demand a steel sheet of improved ductility and surface quality, and therefore an exacting quality control system, described in detail by the author, is essential throughout all stages of processing from raw materials to finished sheet.

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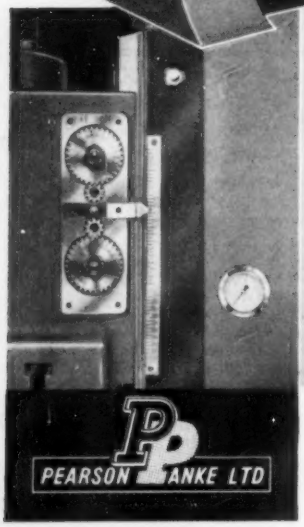

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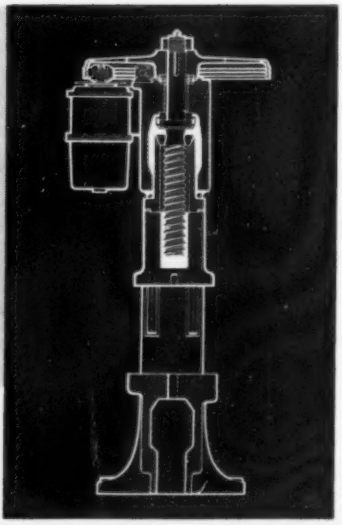

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FOR OUR OVERSEAS READERS

RÉSUMÉS DES PRINCIPAUX ARTICLES

Conception et fabrication de panneaux architecturaux en émail vitreux .. page 622

Une des caractéristiques les plus frappantes des horizons changeants des grandes villes est l'augmentation rapide de l'emploi des panneaux architecturaux en émail vitreux sur les faces extérieures des nouveaux bâtiments. Cet article explique les facteurs qui agissent sur la conception de ces panneaux et décrit les procédés de fabrication employés aux usines de la Société Stewart & Gray Ltd., située à Tooting, Londres.

L'emploi de feuillards galvanisés dans la fabrication d'automobiles aux Etats-Unis page 631

Par K. P. Scott et M. H. Davies.

L'orientation récente des fabricants d'automobiles américaines vers la construction de carrosseries monocoques a été accompagnée par la recherche de matériaux ayant une meilleure résistance à la corrosion; par la suite, on utilise aujourd'hui de grosses quantités du matériau préféré: l'acier revêtu de zinc.

Cette évolution a joui dans le Royaume-Uni d'un intérêt considérable, et ce compte rendu, publié par la Zinc Development Association à la suite d'une visite effectuée par les auteurs aux Etats-Unis, vise à donner un aperçu de la pratique courante dans les Etats-Unis. Bien que ce rapport porte principalement sur les matériaux et techniques employés dans la fabrication des voitures, il comporte aussi, à titre d'information pour les producteurs d'acier, un supplément décrivant quelques unes des techniques spéciales employées pour la fabrication de feuillards de qualité spéciale, galvanisés par immersion à chaud.

Détermination des propriétés d'emboutissage profond de l'aluminium et de ses alliages page 637

Par Robert Chopin.

L'auteur, qui est directeur du Centre Technique de l'Aluminium à Paris, se met en devoir d'établir qu'il paraît impossible de déterminer les propriétés d'emboutissage profond des divers alliages de l'aluminium en se servant des caractéristiques et essais habituels, même dans le cas le plus simple du cylindre.

Il considère que, des méthodes courantes de recherche, seuls les essais

(Suite page 678)

ZUSAMMENFASSUNGEN DER HAUPTARTIKEL

Entwurf und Erzeugung feueremaillierter architektonnischer Füllungsplatten Seite 622

Eines der Merkmale im veränderten Silhouettebild der Klein- und Großstädte ist der rasch zunehmende Gebrauch feueremaillierter Füllplatten an Außenwänden der Neubauten. Diese Abhandlung erklärt die Umstände, die den Entwurf solcher Platten beeinflussen und beschreibt die Erzeugungsvorgänge in den Werken von Stewart & Gray Ltd., Tooting, London.

Verwendung von verzinktem Stahlblech im Kraftfahrzeugbau der U.S.A. .. Seite 631

Von K. P. Scott und M. H. Davies.

Das sich neuerlich bemerkbar machende Streben nach vereinheitlichter Karosseriekonstruktion im amerikanischen Kraftfahrzeugbau hat eine gesteigerte Nachfrage nach Werkstoffen mit verbesserter Korrosionsfestigkeit hervorgerufen, und große Mengen von verzinktem Stahl, dem vorzugsweise verwendeten Material, werden diesem Zweck zugeführt.

Die genannte Entwicklungsrichtung hat in Großbritannien bedeutendes Interesse gefunden, und der vorliegende, als Ergebnis eines Besuches der Verfasser in den U.S.A. entstandene und von der Zinc Development Association veröffentliche Bericht ist als eine Übersicht über den gegenwärtigen Stand der Technik in den Vereinigten Staaten. Er behandelt hauptsächlich die im Kraftfahrzeugbau benutzten Werkstoffe und Verfahren; ein besonders im Interesse der Stahlerzeuger beigefügter Anhang beschreibt jedoch einige der Spezialverfahren zur Herstellung der besonderen Arten von feuerverzinktem Stahlblech.

Bestimmung der Tiefziehbarkeit von Aluminium und dessen Legierungen. .. Seite 637

Von Robert Chopin.

Der Verfasser, Direktor des Centre Technique de l'Aluminium, Paris, zeigt zunächst, daß es offenbar unmöglich ist, die Tiefziehbarkeit der verschiedenen Aluminiumlegierungen, selbst im einfachsten Falle des Zylinders, auf Grund der üblichen Eigenschaftsangaben und Prüfungen zu bestimmen.

Nach seiner Ansicht lassen sich unter den bestehenden Untersuchungsverfahren nur durch vollmaßstäbliche,

(Forts. S. 678)

RÉSUMENES DE LOS ARTICULOS PRINCIPALES

La concepción y producción de paneles arquitectónicos con esmaltado vítreo página 622

Una de las características del aspecto cambiante de poblaciones y ciudades es ul uso, cada dia mayor, que se hace de paneles "vitreoesmaltados" en las fachadas de edificios nuevos. Este articulo contiene información sobre los factores que influyen en la concepción de dichos paneles y describe los procedimientos de producción que se emplean en los Talleres de la Stewart & Gray Ltd., de Tooting, Londres.

El empleo de fleje galvanizado en la fabricación de automóviles en los EE. UU. de A. página 631

Por K. P. Scott y M. H. Davies.

Las tendencias recientes hacia la construcción unitaria de las carrocerías para automoviles americanos ha dado lugar a la demanda de materiales con mejor resistencia a la corrosión y se están ya empleando grandes cantidades de acero cincado, el material preferido.

En el Reino Unido esta tendencia ha despertado considerable interés y este informe, que ha publicado la Zinc Development Association (Asociación para el Perfeccionamiento del cinc) como resultado de la visita que los autores han hecho a los EE. UU. de A., pretende dar cuenta de los sistemas catuales en América. Aun cuando trata principalmente de los materiales y las técnicas que se emplean en la fabricación de automóviles existe un suplemento que describe algunas de las técnicas especiales empleadas en la producción de tipos especiales de fleje galvanizado en baño caliente para que pueda servir de guía a los productores de acero.

Determinación de la capacidad para el estampado profundo del aluminio y sus aleaciones .. página 637

Por Robert Chopin.

El autor, que es el director del Centre Technique de l'Aluminium de Paris, se propone demonstrar que es aparentemente imposible determinar la capacidad para el estampado profundo de varias aleaciones de aluminio por las propiedades usuales y ensayos aun en la más simple forma de un cilindro.

Considera que entre los métodos actuales de investigación únicamente ensayos prácticos a escala natural llevados a cabo con diversos diámetros

(Continuara en p. 678)

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THE TEST OF TIME

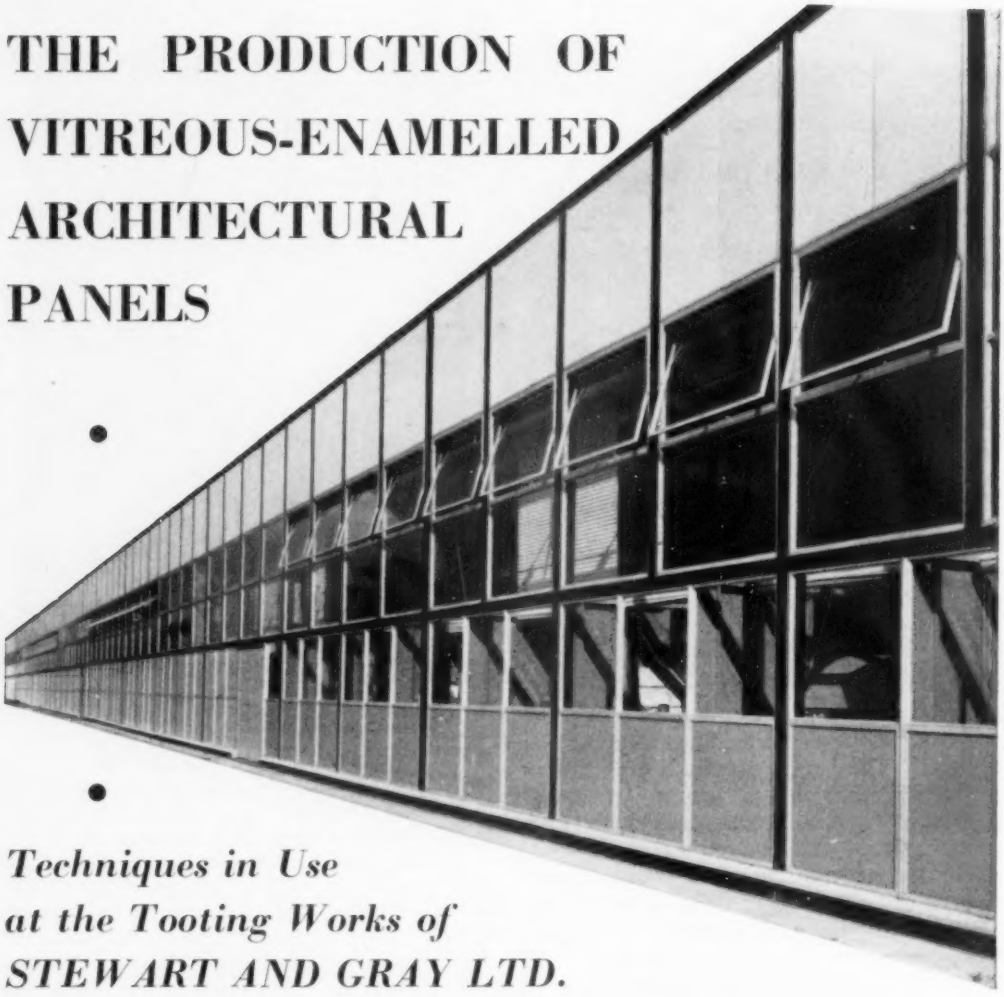
IT is a never-ceasing source of surprise to delve into the history of technology and to find that many processes and even designs of machines, etc., used in industry today are basically the same as they were many generations ago. One has only to turn the pages of Agricola's "De Re Metallica" or look at some of the inventions of Leonardo da Vinci to appreciate this fact. The similarity extends even further as Agricola's comments on "foremen" could well have been written recently (although it is doubtful if they would be printed!).

Throughout technology there are certain "marriages" of materials that have existed from time immemorial, one of these combinations being metal and glass. The evolution of the smelting of metals is too well known to refer to here, but it is perhaps not so well known that glass in the form of glazes for pottery was being made in the Near East as early as 5000 B.C., the glaze being prepared by the fusion of silica sand, shell lime or magnesia limestone and "alkali" which was natural soda or soda ash. In this way prehistoric man also applied glazes to highly-coloured precious stones and pebbles, variegated colours being obtained by the addition of small quantities of copper iron and other minerals. Early text-books on glass making date back to 1700 to 700 B.C. and give detailed information on furnaces and smelting procedures. Glass blowing was not discovered, however, until about 50 B.C. Glass vessels in the early days were valuable but with the advent of glass blowing it was definitely "non-U" in the best circles to have drinking vessels, etc., which were not of metal.

Wherever one reads there is this inevitable simultaneous mention of metal and glass, even though the relationship was not always a happy one. Subsequent developments brought the two materials closer together in the form of enamelled jewellery, etc., and even Bessemer, much better known for his steelmaking activities, in 1846 turned his attention to an attempt to produce glass plate direct from the furnace by pouring the molten glass between rolls.

Today, of course, the marriage of metal and glass is an accepted fact as vitreous (or porcelain) enamel is one of the most valuable decorative and protective media for metals. Elsewhere in this issue we give some details of the production and design of vitreous-enamelled cladding panels for buildings, panels that are so much in evidence in, and lend colour to, the changing skyline of our towns and cities. Although we have lagged behind the U.S.A. in the adoption of this type of cladding, no one, viewing some of the excellent examples of enamelling on show in the museums of the world, or vitreous-enamelled signs which have been, for example, on railway stations for many years, can have any doubts as to the ability of enamel to withstand hard use and the rigours of our climate. With the advent of so many new and often directly competitive materials vitreous enamel can still hold its own in many fields. In the broadest sense it has been in existence for 7,000 years so there is no reason why it should not; the test of time is still a criterion!

THE PRODUCTION OF VITREOUS-ENAMELLED ARCHITECTURAL PANELS

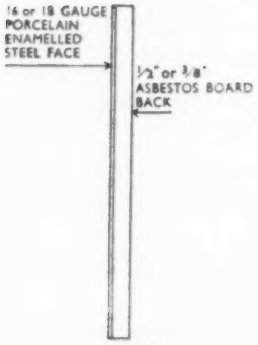


Techniques in Use at the Tooting Works of STEWART AND GRAY LTD.

ONE of the features of the changing skyline of the towns of this country is the rapidly increasing use of vitreous-enamelled cladding panels on the exteriors of new buildings. The process of decorating metals with fused-on enamels is one of the oldest known to man, and its permanence is confirmed by the many beautiful examples of enamels on metals housed in the World's museums. It is only comparatively recently, however, that architects in this country have become widely interested in the process for decorating the exteriors of buildings, although in the U.S.A. the method has been extensively used for over 30 years.

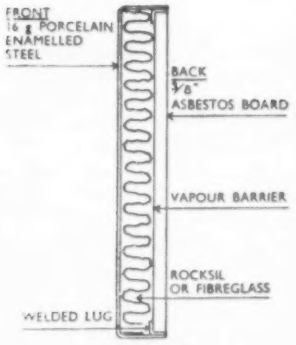
Enamel is manufactured by smelting together at temperatures above 1,100° C. inorganic materials such as borax, silica, soda, felspar and cryolite, together with various metallic oxides. The resultant molten "glass" is quenched in water, the finely shattered material produced being known as "frit." The frit, together with clay, metallic oxide colouring materials and water is then ground in ball mills until the resultant suspension reaches a cream-like consistency. The liquid suspension can then be applied to the component to be treated by

Fig. 1 (above).—Part of the exterior of the works of Ilford Ltd., Basildon, Essex, clad in vitreous-enamelled panels of Type C (see Fig. 2). (Architect: Anthony B. Davis, Chief Architect/Planner, Basildon Development Corporation)



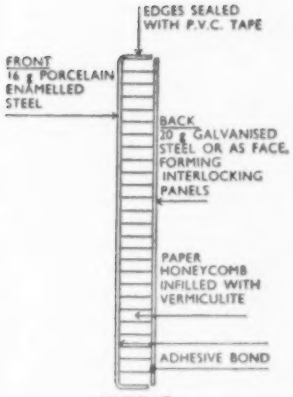
TYPE A

Composite panel consisting of 16 or 18 gauge, vitreous porcelain enamelled steel sheet bonded to ⅜" or ½" asbestos board. The asbestos back panel may also be covered by an enamelled steel sheet or galvanised sheet.
Weight: 5 lb. per sq. ft.
U. value: ·48.



TYPE B

Panel consisting of a 16 G. porcelain enamelled face, flanged all sides with welded corners. The face panel is filled with Rocksil or Fibreglass and backed with ⅜" Asbestos board. A vapour barrier of aluminium foil is placed between the insulating material and the asbestos back. Total thickness approximately 1½".
Weight per sq. ft.: 5 lb.
U. value: ·20.

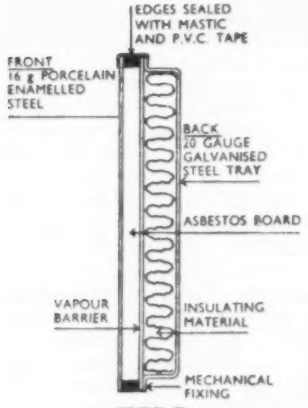


TYPE C

Composite panel consisting of:
16 G. Porcelain enamelled steel face, bonded to phenolic resin impregnated paper honeycomb and 20 G. galvanised steel back. The paper honeycomb cells are infilled with granular vermiculite. The galvanised back sheet may be replaced by an enamelled steel panel. The paper honeycomb is rigid and water resistant.

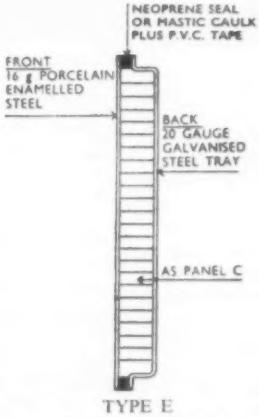
Thickness	U. Value	Weight sq. ft.
¾"	.30	4.0 lbs.
1"	.28	4.1 lbs.
1¼"	.24	4.2 lbs.
1½"	.20	4.4 lbs.

Add ¼" for overall thickness.



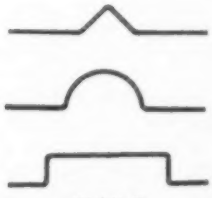
TYPE D

A flat sheet of 16 G. porcelain enamelled steel bonded to ½" asbestos board backed with a tray of 20 G. galvanised steel containing insulation such as Rocksil, cork, strawboard, etc. The final assembly is made by mechanical attachments through the flanges.
Weight per sq. ft.: 6·5 lb.
U. value according to type of insulation.
1" Rocksil = ·20.



TYPE E

A flat sheet of 16 G. porcelain enamelled steel bonded to phenolic resin impregnated paper honeycomb and a 20 G. galvanised back tray. The edge formed by this method of assembly is suitable for use with glazing sections.
U. values and weights as type C.



TYPE F

16 G. Porcelain Enamelled Sheet only.
Flat sheet, flanged, or corrugated form, finished in colour one side or both sides.

Fig. 2.—Details of different types of cladding panels. In type F reeded and embossed designs are also available

spraying, dipping, etc., following which, after drying out the water, the coating is fired in muffle-type furnaces at about 800 to 850° C. The type of enamel and the final finish required decides, in general, the number of coats applied.

A company specializing in the production of vitreous-enamelled cladding panels is Stewart and Gray Ltd., Tooting, London, in conjunction with their associate company Escol Products Ltd., who manufacture the enamel frits. Already the company have been responsible for the cladding of over 1,250 buildings involving panelling area of more than 1,300,000 sq. ft. Some of these are shown in Figs. 1 and 4.

The main type of panels produced are shown in Fig. 2 and the alternative formulations, infills and backings in Table I. In its simplest form, a panel consists of a 16-gauge vitreous-enamelled steel sheet bonded to $\frac{3}{8}$-in. or $\frac{1}{2}$-in. asbestos board. The asbestos-backed panel may also be covered by an enamelled-steel or galvanized-steel sheet. Another typical panel consists of a 16-gauge vitreous-enamelled steel face, bonded to resin-impregnated paper honeycomb with a galvanized steel back. The cells of the honeycomb may be filled with granular vermiculite and the galvanized back may be replaced with an enamelled back if required.

In general the size of panels is limited to a maximum of 8 ft. long × 4 ft. 6 in. wide, although it is preferable not to exceed the recommended dimensions of 6 ft. 6 in. × 4 ft. 6 in. These limits are affected by the construction of the panel chosen, and the company can, in special cases, produce over-size panels of suitable design.

The colour range recommended is to B.S. 101, although special notice has been taken of certain fugitive colours based on gold oxide, which present special problems in firing. In general it can be said that an architect's choice of colour can usually be met, although some colours may be very expensive to produce. The company now has a " library " of about 500 colours and finishes which have been produced over the years, any of which can be reproduced if circumstances warrant so doing.

As a true appreciation of the vitreous-enamelling process is required before a panel is designed, together with its method of fixing, it is strongly recommended that an architect should consult a manufacturer well versed in producing panels before making a design of his own, in case his design cannot be made economically. The company stress, however, that they can make panels to any practicable design, and can also provide embossed panels, fluted panels, etc., which give some relief and depth to what otherwise would be a flat surface. In addition, panels can be produced in more than one colour, or include a design in one or more colours. Typical of what can be done in this way are the county shields on the forecourt of Paddington Station, London, which are reproduced in the appropriate colours in vitreous enamel on a white vitreous-enamel background.

Local fire and other regulations have to be taken into account when making a choice of design for a panel, but the versatility of the material is such that these regulations can usually be complied with. Additional versatility can also apply to the framing system and methods of panel attachment used. For example, the requirements specified for the new Piccadilly Station, Manchester, led to an individual specification which will provide a continuous and uninterrupted band of white enamelled panels all round the building.

The main doubts regarding vitreous-enamelled panels were :—

(*a*) susceptibility to mechanical damage; and

(*b*) ultimate corrosion of the steel at edges.

These doubts have been resolved by extended experience which has shown :—

(*a*) that a ground-coat enamel properly applied will withstand a high degree of violent treatment before its adherence to the base metal is effected; and

(*b*) that adequate protection of edges against corrosion can be ensured by sealing them with p.v.c. tape or similar material before dispatch to site, after which the panel is bedded into its frame in mastic and the sealing against weather is finished off with a face beading and mastic point.

However, it should not be forgotten that vitreous enamel is a glass and the panels should be treated as such. Furthermore, storage of panels on site varies according to the type. For example, asbestos-backed panels should be stored by leaning against a wall with corrugated paper separating the edges. Infill panels should be stacked flat with corrugated paper between all panels and stacks should not be more than 3 ft. high. If the backing to panels is in zinc-coated sheet then they must be stored to prevent moisture collecting between two galvanized surfaces. Protection of the stored panels from moisture is of paramount importance, because moisture can cause deterioration in asbestos board, insulation board and other such materials, and frequently some of the products of deterioration which may be highly basic can cause damage to the enamel surface. Full instructions regarding storage are given on the panels and these should not be disregarded.

If the internal or reverse face of the panel is to be used as an internal wall of the building it can be finished in vitreous enamel, Stelvetite, or printed wallboard so that a ready finished internal surface of the building requiring little maintenance is ensured.

PANEL PRODUCTION

An interesting feature of the works of Stewart

Fig. 3 (*above*).— *This colour photograph shows completed vitreous-enamelled panels being checked with master standards for correct colour*

●

Fig. 4 (*overleaf*).— *Some typical buildings clad with Escol vitreous-enamelled panels:*

(1) *Daily Mirror Building, High Holborn: panel area* 20,000 *sq. ft., panel type A. (Architects: Sir Owen Williams and Anderson Forster and Wilcox, London)*

(2) *Empire House, Chiswick: panel area* 14,000 *sq. ft., panel type C. (Architect: Carl Fisher, Dip.Arch., A.R.I.B.A.)*

(3) *Fire Research Station, Boreham Wood.* 3,600 *sq. ft. of two-colour panels. (Architects: Chief Architect's Division, M.o.W.)*

(4) *Swimming pool of the liner* Orcades. *V-E panels in about* 12 *colours*

(5) *Office block for Wallpaper Manufacturers Ltd., Old Ford, London, E.3. Panel area* 1,800 *sq. ft. (Architects: Ralph Tubbs, O.B.E., F.R.I.B.A.)*

(6) *Borestone Primary School, Bannockburn. Panel type A, area* 6,300 *sq. ft. (Architects: G. S. Hay, A.R.I.B.A.. Chief Architect, C.W.S. Ltd., in association with Sir John Burnet, Tate and Partners, London*

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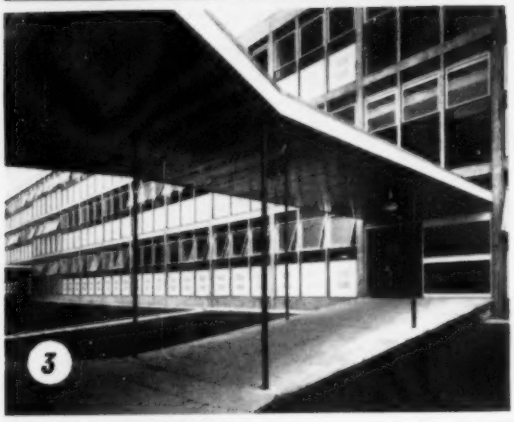
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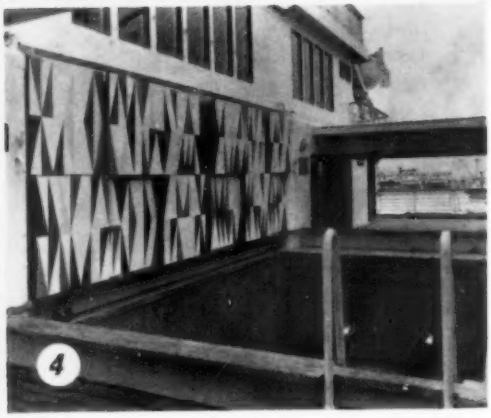
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TABLE I

ALTERNATIVE FORMATIONS, INFILLS AND BACKINGS FOR *ESCOL* PORCELAIN ENAMELLED STEEL INFILLING UNITS

PANEL TYPE	STEEL FACING FORMATION		INFILL/BACKING	REMARKS
A	Unflanged	16 G.	½" Asbestos Insulation Board	Used in cavity wall construction or where inner face is to be decorated, and insulation is of minor importance.
	Unflanged	18 G.	⅛" " " "	Suitable for partitioning and all cases where durable finish is required on both sides.
	Unflanged	18 G. (Enamelled Steel both sides)	⅛" " " "	For use in standard glazing section, edge thickness ⅛".
	Unflanged	16 G.	½" Asbestos Insulation Board backing undersize all round.	Normally, minimum ¾" wide flanges but this is dependent on size.
	Flanged with corners welded.	16 G.	½" Asbestos Insulation Board	Allows unobtrusive vertical joints to be made with horizontal facing beads only, or arranged for screw fixing through flanges.
	Special flange section for butt-jointing.	16 G.	½" " " " ⅛" " " "	
B	Flanged, lugs inside for attaching backing.	16 G.	Fibreglass or Rocksil Vapour barrier backed ⅛" Asbestolux secured with screws.	This unit being mechanically assembled does not offer the same degree of flatness and rigidity as bonded formations.
			With additional skin of Asbestos Insulation Board bonded inside.	Increased rigidity and insulation.
			This type backing may be replaced with Eternit or Hardboard.	
			Backing panel may be omitted, being replaced by aluminium foil, enshrouding loose infill.	For cavity wall construction.
C	Flanged	16 G.	Honeycomb/Vermiculite, backed with 20 G. Galvanised steel. Infill thickness from ¼" to 2".	Used in cavity wall construction or back is decorated as internal face.
			¾" Insulation Board in place of Honeycomb. Galvanised steel replaced with aluminium foil.	
			Additional bonded skin of Eternit Wallboard D or Hardboard.	Backing used for internal decoration.
			Infill of Cork, backed with 20 G. Galvanised steel. ¾" to 2" thick. Galvanised steel backing replaced with additional bonded skin of Eternit Wallboard D or Hardboard.	
D	Unflanged	16 G.	⅛" Asbestos Board and ¾" Fibreboard, with 20 G. Galvanised tray. Bonded sandwich. Edge thickness ⅛". Fibreboard may be replaced with Cork for increased insulation. (No increase in edge thickness.)	
E	Unflanged	16 G.	As for type "C".	In cavity wall construction, galvanised backing is recommended, otherwise alternative backings as for "C".

All edges are sealed with P.V.C. obviating drying out of mastic used in fixing, and giving added edge protection.

As an extra, exposed face of Asbestos Insulation Board may be sealed with aluminium foil, rubberised paint or bitumen.

Standard finishes are gloss, semi-matt, or matt for most colours in the British Standards 101 or Munsell ranges.

and Gray Ltd. is that the plant was originally laid out as a jobbing plant for the production of cookers, washing machines, etc. and was adapted to the production of architectural panels about six years ago. The most unconventional feature of panels in relation to normal jobbing enamelling is their size, and the fact that a wide range of dimensions has to be catered for. Consequently, one of the main problems in the works is that of handling, and when in the wet enamel or biscuit stage much of the handling may become a two-man job, which is not the case with more conventional enamelling. Because of the large size and complexity of shape of the panels, mechanical handling introduces special problems, the solution of which may well be governed by the floor space available as a suitable conveyor would by normal standards, have to be very large.

The three basic types of enamelled panel are the flat sheet, the flanged panel with fully welded corners and the box-type panel (*see* Fig. 2) which has an additional inward return flange to facilitate the mechanical fixing of a rigid insulation material to the back of the panel. Where necessary corners, etc. are welded. Whatever the form of the panel, however, the success attained in enamelling will largely be judged by its ultimate shape and flatness. Consequently, apart from such basic rules as, for example, ensuring that the flange width is adequate for the size and design of panel concerned, no specially designed panel is regarded as satisfactory for production until a prototype has been fully processed and tested afterwards.

The fabrication of the panels follows normal sheet-metal practice, the principal tools being the guillotine and press brake, for which special goose-neck tools have to be used for producing box-types. In the main 16-gauge enamelling-quality steel is used for all panels.

Pickling presents no problems other than those involved with the size of the panels, and as the panels are fabricated, not pressed, a hot aqueous degreaser is adequate for grease removal.

After cleaning, inspection is carried out for faulty welds, etc. Surface scratches, which frequently occur during fabrication, are stoned down, particularly as all panels are subsequently fired in the vertical position and a scratch can cause blisters or can disfigure the panel.

Ground Coat

The application of ground coat to steel panels of this size presents a number of problems, not the least of these being the actual choice of ground-coat frit. As the panels have to be fired vertically the question of enamel drag must influence this choice, and therefore the ground coat must have a low fluidity at the fusing temperature. On the other hand, it must possess sufficient fluidity to prevent a tendency to "copperhead" at the minimum application thickness. In addition, and because of the panel size and in the case of flanged and welded panels, a ground coat with as low a firing temperature as possible is required to keep distortion to a minimum. The ground coat used, therefore, has a composition of 50 per cent hard, 20 per cent medium and 30 per cent soft frits, the fusing temperature being 830° C.

Fig. 5.—Application of ground coat by swilling. The sheet is placed in a draining position and the enamel, which is pumped from a sump, poured along the top edge of the panel so that it drains down the panel, completely covering it

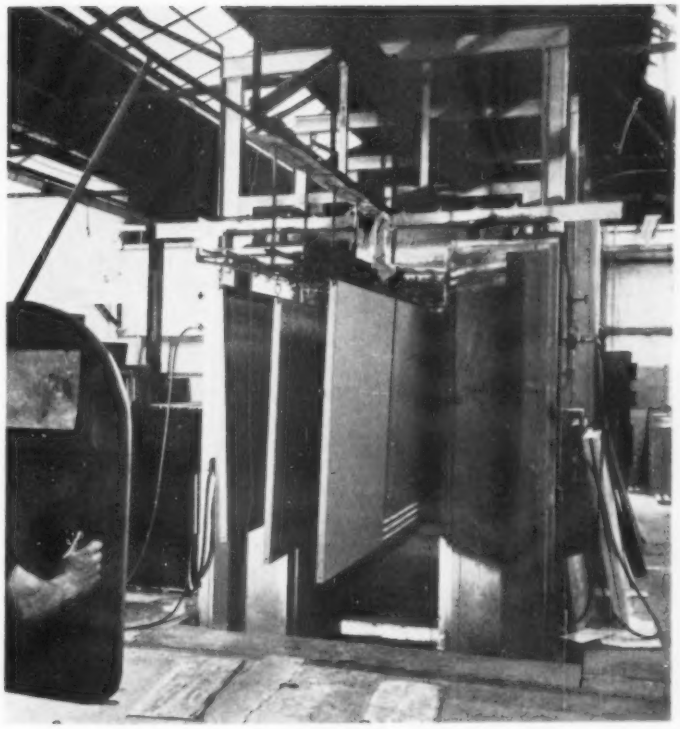

Fig. 6.—Electrically-heated furnace for fusing ground coat. The box-type panels shown are for the largest vitreous-enamel-clad building in the U.K., the C.W.S.-C.I.A. building in Manchester. It is twice the size of the "Daily Mirror" building in London and has 3,200 panels, an area of 45,000 sq. ft. (Architect: Ralph Tubbs, O.B.E., F.R.I.B.A.)

Originally the ground coat was applied by spraying, this method having the advantage that no special properties as regards to set, viscosity and specific gravity were required. However, spraying had the disadvantages of low speed of application, irregularity of application and excessive waste of enamel.

Current practice is to apply the enamel by swilling and the two problems which had to be solved before this method was successfully used were the ground-coat milling formula and specifications and the method of swilling.

As panels may vary in size from about 1 ft. 6 in. × 9 in. to 8 ft. × 4 ft. 6 in., the ground-coat slop has to possess draining properties which are suitable for long and short draining lengths and also some differences in draining angle. At the same time it has to provide a minimum variation of thickness on any given panel. Successful use of this method is now given in a mill formula containing 4 per cent white clay, 3 per cent yellow clay and a relatively low water content of 56 lb. per 100 lb. of frit. To avoid producing an overset condition, grinding is rather coarser than usual, *viz:* to between 10/12 cc. frit retained from a 50-cc. sample on a 200-mesh lawn. In addition, the electrolytes are kept to a minimum. The resulting slop has a specific gravity of 1.68 to 1.7, the wet pick-up on a 2-ft. square sheet being 5 to 5½ oz.

The method of swilling the sheet (Fig. 5) consists in placing the sheet in a draining position and pouring the enamel along the top edge so that it drains down the sheet, completely covering it. The ground-coat enamel slop is delivered through a flexible hose from a diaphragm pump, the surplus enamel draining into a sump from which it is recirculated. The equipment incorporates a magnetic separator and a sieve in the circuit so that the enamel is delivered to the sheet surface uncontaminated.

Preliminary drying of the ground-coated panels is effected by stacking them flat in wheeled racks.

An electrically-heated furnace (Fig. 6) with pneumatically operated sliding doors is used for fusing the ground-coated panels, which are hung on a fusing jig which is manually introduced into the furnace on an overhead monorail. All panels are fused hanging lengthwise in a vertical or near vertical position except when oversized, in which case they are either fused supported by a leaning jig or are fired flat on expanded metal in a conventional lay-down furnace.

For handling the flat panels two small clips are welded on to one edge with holes to take the fusing

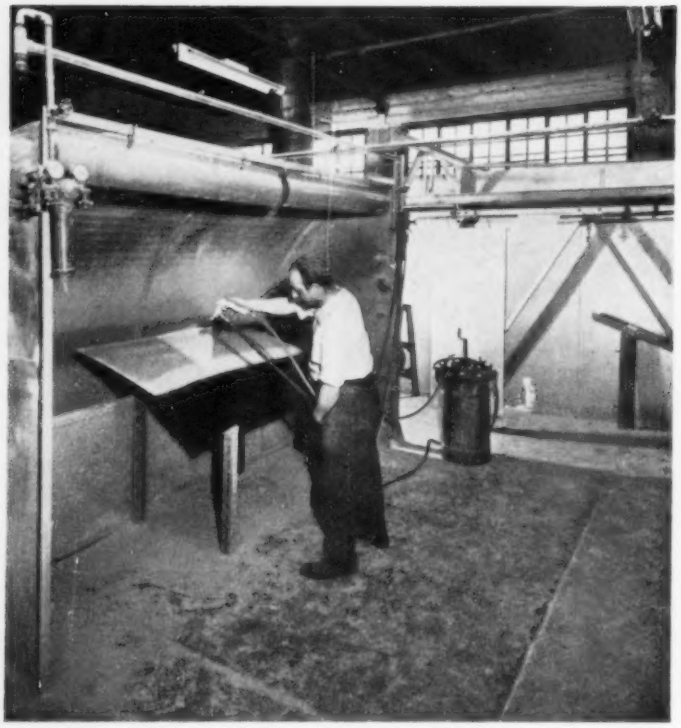

Fig. 7.—Application of cover coat by spraying. (Equipment is by Aerograph-DeVilbiss)

hooks; these clips, which are placed mid-way between the centre and the end of one short dimension, are sawn off after enamelling. Flanged and box-type panels have holes drilled in the flange to take similar hooks.

It is essential to take every possible precaution to eliminate distortion, either in design or in practice. Should undesirable distortion take place, however, it is often possible to straighten a distorted panel by firing flat in a lay-down furnace, but this operation is expensive, and also can effect the panel colour, and rectification of colour by respraying and refiring is the shortest path to ultimate rejection.

Cover Coating—General Problems

Since colour is such an important feature of architectural panelling—and the great range of colours available is one great advantage of vitreous-enamelled panels over others of different materials—colour matching and colour control become vital parts of production. Clients may call for colours from any colour range from B.S. 2660 to Munsell, including any paint manufacturer's colour card. Less co-operative architects can, and do, request colours half-way between two other colours or matchings to house bricks, pieces of paper, fabrics, or even verbal description. Matching of new colours is therefore a more or less permanent necessity. Uniformity of colour is probably more important than the actual colour matching, and the first step to uniformity is to test the stability of each milled enamel after its colour has been matched. This is carried out by fusing 4-in. squares of steel sprayed in the enamel over a range of temperatures beginning at 20° C. below the production fusing temerature and finishing 20° C. above. These squares are then examined, and depending on the degree of variation between the extreme of under-firing and over-firing, either accepted or rejected for production. Rejection means re-matching with alternative oxide bases, and should stability still prove impossible, the stable colour nearest to the one required is submitted for consideration, rather than attempt to produce panels in an unstable enamel. The next stage in colour-control is to check every mill load of enamel for colour, first by firing a 4-in. square in a small electric furnace and then a 4-ft. × 1 ft. production sample fired in the production furnace. When inspecting the completed panels for colour, one panel in the production run is used as the master sample and each panel is compared to this, on an easel placed in a specially constructed matching booth lit by artificial strip lighting (Fig. 3). No deviation from the sample is

Fig. 8.—Drier for cover-coated panels

allowed and should a variation in colour occur, every attempt is made to bring the colour back to the master by re-firing or re-spraying. Failure to achieve uniformity of colour by these methods leads to stripping and re-enamelling. The last step in colour control is to fuse a 12-in. square with the production run so that an exact record of the colour of the given batch of panels can be kept, which will prove of great value should an extension to a building or a replacement panel be required at subsequent time.

The finishes called for in architectural enamelling come under four headings: (*a*) full matt; (*b*) semi-matt; (*c*) semi-gloss; and (*d*) gloss. It is, however, the policy of the company to restrict these wherever possible to semi-gloss and gloss. In the opinion of Stewart and Gray Ltd. the full-matt and semi-matt finishes lend themselves too easily to dirt retention and tend to become unsightly after weathering if not regularly cleaned down. This applies more particularly to dark and extremely light colours. The former are disfigured by the normal products of degradation of other materials on the building, such as paint, cement and aluminium, all of which give rise to white deposits which stand out very markedly on a dark background. Extremely light colours are susceptible to the black grime from the atmosphere. If insisted upon, the company are prepared to process light colours and pastel shades in semi-matt enamels, but full-matt finishes in any colour are excluded from the range.

The frits necessary to produce the range of finishes are :

1. A.R. clear frits for dark colours, reds, yellows and bright colours.
2. A.B. semi-opaque frits for medium colours.
3. A.R. semi-opaque frits with relatively large additions of opacifier for light colours and pastel shades.
4. A.R. self-matt frits for pastel semi-matt finishes, and
5. Self-opacifying frits for white gloss and a restricted number of pastel shades.

The semi-gloss finishes are obtained from the above frits by : (*a*) mixing " incompatible " frits ; (*b*) introducing relatively large amounts of quartz to the mill; and (*c*) for pastel shades by combining a quartz addition with a high proportion of opacifier added to the mill. The bright colours, for example yellow, are normally applied over a self-opacifying titanium white base coat. Without exception finishes are obtained by two-coat application. Moreover, every panel is always given a coat of cover-coat enamel on the reverse side to afford extra protection and to minimize distortion. The reverse side is then over-sprayed in a highly refractory enamel which produces a rough porous surface after fusing, and provides an excellent key for the adhesives used in bonding.

Cover-coat application is, of course, best carried out by spraying the panels hanging on a conveyor which then passes through the drier (Fig. 8). When space limitations prevent this, specially enlarged spray booths (Fig. 7) can be used quite satisfactorily, but transfer of panels to the conveyor drier must then be done by hand. The spraying of very large panels brings its own problems which will be only too obvious.

Inspection

Apart from the question of colour, inspection of the panels runs on the same lines as with any other enamelled product. Every attempt is made to salvage rejected panels by repair and local re-spraying, and unless a panel is too badly distorted or dented the last recourse is to strip and re-enamel. Enamel stripping is carried out by blasting with very fine abrasive and has proved to be very satisfactory. This is helped, of course, by the 16-gauge steel.

Multi-colour and Special Finishes

Some variations from the normal plain colour panel are occasionally required, and both mottled and stippled finishes have been produced in some

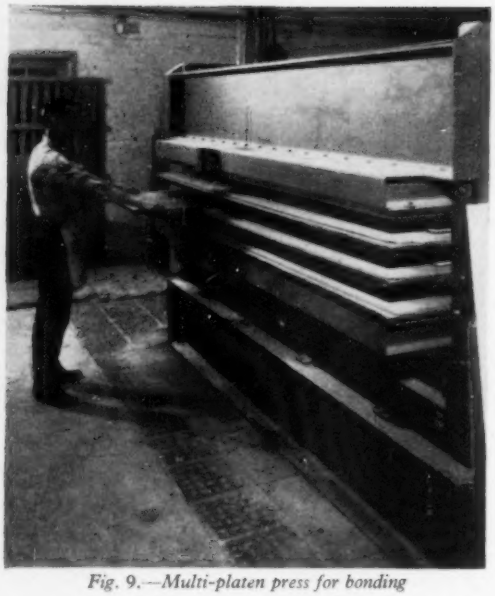

Fig. 9.—Multi-platen press for bonding

quantity. The stipple is produced by heavy mottling of the sprayed base colour with the same enamel, using a mottling gun adjusted to give the largest possible spot. The fused appearance is an exaggerated orange-peel effect, which in some opinions is a pleasing one.

Multi-coloured panels are also produced to meet architects' requirements, which necessitate a number of additional fusings. One of the most popular of these is the diaper pattern in which the rectangular panel is divided by diagonal lines into four triangles. Each triangle is finished in a different colour giving the effect of relief to the finished panel.

Masking tape is used to facilitate the spraying of each triangle, and the panel is fused after each colour application.

One of the main problems to be contended with is the progressing of each job through the plant to ensure that every panel on the job is passed over to the bonding department in one batch. This entails storage of panels in the enamel shop until every panel held up for re-spray, repair or replacement, has been passed by inspection. With perhaps 50 different jobs passing through the enamel shop at any one time, the need to keep them separate produces problems which can only be overcome by accurate progressing.

Bonding

The range of infill and backing materials is so wide that it is not possible to detail the application of each to the panels. It is sufficient to say that the process of bonding is carried out in a multi-platen press (Fig. 9). All edges are afterwards sealed with p.v.c. tape which gives protection to the edges against corrosion, and also prevents oils from the mastic used in fixing from drying out by absorption of their solvent oil by a porous backing material (such as asbestos board). It is also possible to seal the exposed edge of an asbestos board with aluminium foil, rubberized paint or bitumen as required.

General

Manufacturers who have to prepare estimates of cost for panel formations called on to meet special requirements must take certain points into consideration.

(1) They must know the approximate size and quantity of panels needed. They must also decide whether a very large panel would better be made by splitting vertically should this be acceptable to the client.

(2) They must know something of the details of the building construction, such, for example, as whether the walls are cavity or solid; whether the inner face of the panel is to be decorated by the main contractor or has to be supplied in finished form by the panel manufacturer. They must have some knowledge of the location and conditions of the site, particularly in relation to storage and panel erection.

(3) They must know the required " U " value called for.

(4) It is useful to have some idea of major building regulations that may be applicable to the building under consideration.

Acknowledgements

Thanks are expressed to Stewart and Gray Ltd. for permission to publish this article, and in particular Mr. D. Mill for his assistance in its preparation.

International Deep Drawing Research Group

FOLLOWING the highly successful Colloquium on Forming and Testing of Sheet Metal held in Paris in May, 1960, it is planned to hold a further meeting in Düsseldorf on May 23 and 24, 1962, under the joint ægis of the International Deep Drawing Research Group and the Verein Deutscher Eisenhüttenleute.

It is proposed to devote the open sessions of this meeting to the presentation and discussion of papers on: (1) Speed Effects in Sheet Metal Forming and (2) The Influence of Surface Conditions on Deep Drawing.

Offers of papers (in English, French or German) or requests for further information regarding this meeting should be addressed either to: John Hooper, Esq., Secretary, I.D.D.R.G., John Adam House, John Adam Street, Adelphi, London, W.C.2., or to Geschaftsfuhrung des Vereins Deutscher Eisenhüttenleute, Düsseldorf, Breite Strasse 27.

The Use of GALVANIZED STRIP IN AUTOMOBILE MANUFACTURE in the U.S.A.*

By K. P. SCOTT† and M. H. DAVIES‡

INTRODUCTION

ZINC-COATED steel has been used in motor-cars for many years. Fuel tanks, silencers and exhaust pipes, the ventilation system, window winding mechanisms, head and tail lamp assemblies are typical examples of the many applications which have in the past been restricted to fittings.

Recently the effect of corrosion on the strength as well as on the appearance of motorcars has forced American automobile manufacturers to use more corrosion-resistant materials in critical areas of the main body and underbody assemblies. Changes in methods of construction *i.e.* where unitized bodies, constructed out of relatively light-gauge sheet, have replaced the conventional chassis and body type of assembly, are mainly responsible, but the increasing use of salt on the roads, for de-icing purposes, is also a major factor.

Of all the commercially feasible protective finishes evaluated by the industry, only zinc coatings have so far provided the required combination of properties with respect to forming, spot welding, and finishing.

The marked growth in demand for zinc-coated sheet by the U.S. automobile industry during recent years is shown in the table below. In addition to hot galvanized and electrocoated sheet it is estimated that approximately 9,000 tons of zinc dust (for paints) were used by the automobile industry in 1960.

Year	Hot Galvanized Strip (*short tons*)	Electrocoated Sheet (*short tons*)
1955	49,376	38,032
1956	58,801	32,256
1957	82,910	41,286
1958	93,967	39,248
1959	106,625	51,655
1960	172,797	46,163

* A report published by the Zinc Development Association.
† Imperial Smelting Corporation.
‡ Zinc Development Association.

The growth of continuous galvanizing in the U.S.A. has been rapid since its inception in 1936 and the new requirements of the motor-car companies have further stimulated production of galvanized strip and also the development of special finishing techniques. At the end of 1960 there were 37 working lines, owned by 12 organizations. A further two lines were under construction and scheduled for production in 1961 and one more is expected to be completed by mid-1962. Of particular interest is the trend towards very wide (up to 80 in.) strip galvanizing lines, partly due to the current and probably future needs of the motorcar industry. This report deals mainly with practice in automobile manufacture but an appendix outlines some of the more important features of the production of galvanized strip for motorcar applications.

Production of Galvanized Strip

Although the demand from the automobile industry has imposed certain problems, there is little doubt that the development has been welcomed by the steel industry and every effort has been made to meet requirements. Initially, sheet with a differential zinc coating was required in order to minimize spot-welding difficulties. Advances in spot welding, however, have resulted in a growing demand for uniformly coated sheet possessing a minimized spangle (smooth finish) and a nominal coating weight of 1¼ oz. per sq. ft. While some differentially coated sheet was still being supplied, it is anticipated that demand for this product will cease in the near future.

One of the main problems imposed upon the

galvanizers has been the need to produce smoother finishes by reducing the spangle on the sheet. In most cases, this has been achieved by spraying both sides of the strip with steam shortly after its exit from the zinc bath. The type and size of jet used was important as also was the degree of saturation of the steam. (Cold dilute copper sulphate solutions were used to spray the surface in one case.)

A further refinement in finish was obtained by giving the product a final skin pass through grit-blasted rolls, the sheet undergoing between $\frac{1}{4}$ to 1 per cent reduction in this operation.

It was universal practice in the U.S. steel industry to supply material to make a specified component and not according to a particular specification for composition or mechanical properties. It has been found, however, that for identical steels, the galvanized product was the more difficult to form and consequently a higher quality base metal was sometimes required as a feed material to the galvanizing line.

Normal practice of the steel companies was to supply the sheet or strip with a chromated finish as an anti-wet storage stain measure. Because of alleged difficulty in welding through the chromated surface, however, all sheet and strip now supplied to the motorcar industry is oiled only. Dry material had on occasion been used but was less satisfactory during drawing operations.

While the standard quality sheet ($1\frac{1}{4}$ oz. per sq. ft. nominal coating weight) is the predominant requirement, there is an undoubted trend towards tighter specifications and hence closer control over coating thickness. A minimum coating weight of 0.45 oz. per sq. ft. per side as measured by the triple spot test and 0.40 oz. per sq. ft. per side by a single spot test (as specified in A.S.T.M. A93) has, for example been requested in some cases. The normal maximum variations in coating thickness ($\pm$10 per cent variation on any one side and $\pm$20 per cent from front to back) have had no significant effect on the welding or forming operations. Nevertheless, steel companies are actively engaged in the examination and installation of electronic devices to control coating thickness.

Automobile Manufacture

Considerable tonnages of hot-dip galvanized strip and also of zinc rich paints have been used together with a limited amount of electrogalvanized (one-side coated) strip for the protection of underbody sections and skin panels. At the present time, however, special grades of hot galvanized strip are the materials most commonly used for corrosion prone parts of the underbody assemblies. Where skin panels are coated (*e.g.* bottom of doors, quarter panels and wings), these are usually coated on one side only by spray painting with zinc-rich paints.

The presence of the zinc coating has raised problems mainly in connexion with spot welding, but also in presswork and in final painting. While each of these problems has been overcome to the extent that acceptable production line techniques have been developed, there is still room for improvement in the materials and in the methods of assembly and finishing.

The knowledge and experience so far gained by the American industry should, however, prove invaluable to the British motorcar and galvanized-strip industries.

Materials Used

Hot-Dip-Galvanized Strip

Initially because of difficulties associated with spot welding (large amount of tip dressing required) differentially coated strip (0.15 oz. per sq. ft. on one side and 0.5+ oz. per sq. ft. on the other) found favour. The differentially coated material certainly gave better electrode performance but was more costly since it necessitated a premium for wiping and marking.

One-sided coated materials were also developed, but have found limited use for a brief period.

At present, uniformly coated sheet ($1\frac{1}{4}$ oz. per sq. ft. nominal) with a matt or spangled finish is being used successfully, due to the improvement in quality control and also in the spot welding techniques. These materials are used to fabricate sections of the underbody and also the rocker panel (or bottom door sill). So far they have not been used for large skin panels.

Zinc-Rich Paints

Doubts about the ability to spot weld galvanized sheet under production-line conditions, and further doubts about the availability of continuously hot galvanized strip initially caused one company to employ zinc-rich paints to protect critical areas of the underbody and skin panels. During the last three years, however, hot-galvanized strip has progressively replaced zinc-rich painting for the underbody sections, although the latter technique has been retained for treating the mating surfaces of large floor panels and also parts of the internal surface of doors and wings.

Electrogalvanized Strip

Apart from the traditional uses of electrogalvanized sheet, the only new application of note is for the skin panel covering the rear mounted engine of one vehicle.

Galvannealed Sheet

Although used for silencers etc. this material has not proved successful for normal presswork because of the fragmentation of the coating in the dies.

Practice in Motor-Car Production

Choice of Steel

It is standard practice to supply steel to make a

particular part and not to adhere to rigid specifications for mechanical properties or composition.

In general it has been found that a slightly higher quality steel (as galvanized strip) is required compared with the grades of uncoated sheet used in the industry. This is due to the changes in the properties of the material which occur at galvanizing temperatures.

Aluminium-killed non-ageing steels are used for parts which involve severe drawing and typical properties, quoted by one steel manufacturer, are as follows:—

U.T.S.	50,000 lb. per sq. in.
0.2 per cent Yield	37,000 lb. per sq. in.
Elongation (on 2 in.)	38 per cent
Hardness	<50 Rockwell B
Olsen	380 mm.

(In other cases the Rockwell B values may rise to 53-56, but elongation and cupping test figures are as above.)

Rimming steels are used for parts not so severely worked, and here the hardness may rise to Rockwell B 55 or more.

Another major supplier to the industry quoted the following as typical properties.

(i) Rimmed steel, not temper rolled, 20 gauge and thicker.

U.T.S.	50,000 lb. per sq. in.
Yield stress	40,000 lb. per sq. in.
Elongation	30 to 35 per cent
Hardness	50 to 55 Rockwell B

(ii) Box-annealed, aluminium-killed steel, with 0.25 per cent temper rolling.

U.T.S.	45,000 lb. per sq. in.
Yield stress	35,000 lb. per sq. in.
Elongation	35 per cent min.
Hardness	45 Rockwell B

Scribed panels are increasingly being used to assess the ductility requirements in particular forming operations and thus help to define the choice of steel. In some cases it has meant that the more expensive aluminium-killed steels have been replaced by rimming steels.

Coating Weight

The broad requirement is for sheet meeting the following coating weight specification.

coating weight	*oz. per sq. ft.*	
minimum	0.8 (both sides)	single spot test
minimum	0.9 (both sides)	triple spot test
maximum	1.65 (both sides)	

Finish

The standard 1¼ oz. per sq. ft. (nominal) coated sheet with a spangled surface is being used by one manufacturer for the underbody sections.

Another major manufacturer demands a matt surface with no visible spangle.

The matt finish is produced by steam cooling and the strip may be given a subsequent pass through grit-blasted rolls in order to produce a "minimized spangle-satin finish" grade for some sections.

(A reduction of up to 1 per cent (usually ½ to ½ per cent) in the temper rolls results in a decrease in the elongation values of the sheet.)

Sheet is supplied oiled only and not chromated.

Forming

Apart from a tendency to give slightly more generous radii, no extra allowance is made for galvanized sheet compared with uncoated sheet of the same thickness. The sheet and/or dies must be well lubricated, and no zinc pick-up on the dies is then experienced. In practice die life is found to be increased.

Lancing techniques, where applicable, are used to assist metal feed in the dies.

Spot Welding

While satisfactory techniques for spot welding galvanized sheet are well established, the rapidity with which welds are made in motorcar production has created special problems mainly due to:—

(*a*) Zinc pick-up on the electrodes which leads ultimately to increased tip area, and therefore decreased current densities and poor welds.

(*b*) The need for more frequent electrode tip dressing, arising from (*a*), and which interferes with production and increases the cost.

There are a large number of factors which influence electrode tip performance and weld properties. They include:—welding conditions (time, current and load), electrode material and electrode shape, cooling efficiency.

For successful welding, proper selection and control of the welding conditions is more vital with galvanized than with uncoated sheet. Ideally, feedback control from the weld is desirable but machines which incorporate a control mechanism of this type are, at the present time, too expensive. "Slope control" *i.e.* the gradual build-up of current offers some advantages but is not widely practised. In the majority of cases simple adjustments have been made to the welding conditions and satisfactory results have been obtained.

General practice is to increase the current and pressure by about 50 per cent and to increase weld time by about 20 per cent compared with normal practice on uncoated steels. (These represent increases of about 10 per cent on current and pressure compared with S.A.E. recommended practice for uncoated sheet.)

Tip Shape. In spite of the increased difficulty of alignment, tapered tips appear to offer marked advantages with respect to zinc pick-ups. There is consequently a pronounced trend towards truncated cone tips although radiused tips and parallel flats are also used.

Tip Material. Although advantages are claimed

for the copper-zirconium alloy tips, the copper chromium alloys (*e.g.* Mallory No. 2) are more commonly used. Tests now in progress will, it is hoped, establish the superiority of one or other type of alloy.

Tip Cooling. In spite of experimental evidence to the contrary most welding engineers stress that efficient cooling is a critical factor in obtaining improved tip lives. For truncated cone tips waterhole/flat face distance of $\frac{3}{8}$ in. are used but a reduction to $\frac{1}{4}$ in. is thought to be desirable.

It is clear that the frequency of welding will largely determine the rise in tip temperature, and hence the extent of zinc build up on the tip.

Tip Dressing. The frequency of tip dressing depends on the particular spot-welding operation. Thus hand guns, operated at high speeds and making hundreds or even thousands of welds an hour, will require much more frequent dressing than the electrodes on multi point automatic welding machines for sub-assemblies.

The electrode tips on hand welding guns may either be dressed *in situ* or rapidly replaced for dressing to be carried out elsewhere. In the former case special pneumatic tools have been developed by one company which will dress the conical surfaces (to remove zinc build up) of truncated cone tips but leave the "conditioned" flat face untouched.

For the multi-point automatic welders, where frequent tip dressing would be unacceptable, the conditions are such that average tip lives of 2,500 spots are being achieved. This permits dressing at least at half shift intervals but under favourable conditions 3,500 spots can be achieved permitting full shift operation without the need for tip dressing.

Variations in coating thickness, within the specified limits do not appear to have an appreciable effect either on tip performance or the properties of the weld.

Typical Conditions. Examples of the welding conditions for 0.040-in. sheet used at the present time are as follows:—

Tip Shape	$\frac{1}{4}$ in. dia. with 45-deg. angle	$\frac{1}{4}$ in. dia. with 20-deg. angle	$2\frac{1}{2}$ in. rad.
Load	625 lb.	700 lb.	700 lb.
Current, amp. (60 cycle a.c.)	12-14,000	12-14,000	12-14,000
Weld time ..	13 cycles	13 cycles	13 cycles

For 0.078-in. material the diameter of the truncated cone tips is increased to $\frac{5}{16}$ in.; weld current is increased to 20-22,000 amp.; weld time is increased to 21 cycles; and the load is increased to 1,400 lb. (for the 45-deg. tip) and to 1,680 lb. in the other two cases.

Weld Checking. A simple chisel test is used almost universally to check for satisfactory welding on the production line. "Peel" tests which reveal the size of the weld nugget are, however, becoming more common.

Paint Finishes

The use of hot galvanized strip is largely confined to the underbody where problems of obtaining a high-quality paint finish do not arise.

However, some strip is being used for visible parts, such as the rocker panel (bottom door sill), and there is also a trend towards the use of coated sheet for skin panels. In these cases it is desirable to obtain, with the same paints, a finish that will compare with the finish obtained on uncoated steel sheet. In the past it was the practice of one company to scuff the exposed galvanized surface using also a Parker 34 phosphating solution. This would be followed by normal phosphating of the whole assembly. At the present time, however, this practice is being replaced by a single phosphating step (using Parker solution No. 37) which allows a good finish to be obtained on the special grade of hot-dip galvanized sheet (minimized spangle satin finish) which is preferred for exterior panels. It has been claimed in one case that a finish equivalent to that on uncoated sheet can be produced. The new phosphating treatment is also claimed to give better chip resistance on coated and uncoated steels. (Spangled surfaces cannot be used since after weathering the spangle shows through the paint.) The hot sprayed phosphating process (Parker No. 37) also eliminates local growth of phosphates (pimpling) which sometimes occurs with the 34 solution.

Zinc-rich Paints

One major manufacturer has in the past made considerable use of zinc-rich paints for protecting the interior surfaces of underbody members and also of skin panels. Although hot-dip galvanized-strip is progressively replacing zinc-rich paints, there will still be some demand for these latter materials. In addition to the spray application of zinc-rich paints to the whole or part of the surface of fabricated sections, there is also interest in the one side coating of strip, by roller techniques. In the latter case a great deal of development work has been carried out, but so far no paint has been developed which will permit forming and also be satisfactory for welding. Deformability is essential since it is the internal surfaces of closed-up box sections etc. which require the added protection of zinc. (Solvent washing of normal paints to leave exposed steel on internal surfaces is one of the main objections to conventional protective systems.)

For spray application, the zinc-rich paints should be applicable to oily surfaces, should be weldable and also must have satisfactory corrosion resistance. Very many paints were examined and at the present time Ionoclad and Zincolate are probably the most

important proprietary paints although several other manufacturers have produced zinc-rich paints which meet the requirements of the motorcar companies. None of these paints, however, is suitable as a primer for external surfaces, since high paint absorption makes them unsatisfactory for over painting to produce the necessary high gloss finish. In all cases, therefore, where panels are sprayed on one side, great care is taken to remove any of the over spray from the external surfaces. At the present time about 10,000 tons of zinc dust is used for paint manufacture in the U.S.A., and of this approximately 9,000 tons was required by the motorcar industry in 1960. A long oil alkyd is the main vehicle of the paint for car finishes and fine grades of zinc dust with all particles below 20 microns are preferred.

Other Finishes

Because of the doubt about the suitability of galvanized surfaces as a base for standard external paint finishes, there is still considerable interest in one side coated material, and this may prove to be the ultimate requirement of the automobile industry. A number of processes for producing this type of product are under investigation. In hot dip galvanizing they are based on precoating the steel strip with a compound to prevent it becoming wetted by molten zinc. Sodium silicate and sodium aluminate have been used but have not been entirely satisfactory, since they allow the masked surface to be partially coated. Scratch brushing to remove local zinc is, therefore, required and results in undesirable scoring of the steel sheet. One steel company claimed that they had developed a water soluble borate masking compound which eliminated this objection.

Electrogalvanized strip (one-side coated) is currently being used and it is possible that greater quantities of this material would be required if coatings of adequate thickness could be provided at a cost comparable with hot dip galvanized sheet. Development work is in progress on fast plating techniques.

Proposals for cladding steel strip with sheet zinc or zinc alloys have also been examined, but it is unlikely that such clad material could be produced at a sufficiently low cost.

Conclusion

Zinc-coated sheet, principally hot-dip galvanized, has been established as the most suitable material for certain parts of automobiles subject to severe corrosion.

The introduction of this improved material has involved some modification of the techniques for fabrication, assembly and finishing, but the changes have been relatively slight.

A gradual conversion to unitized construction for all vehicles, and in addition an extension of use (governed partly by cost) to more components will lead to a marked increase in consumption of galvanized sheet by the automobile industry. In the U.S. alone it is estimated that approximately 800,000 to 1,000,000 tons per annum of hot-dip galvanized sheet will be required by 1965.

The results of development work in the automobile industry, particularly with respect to spot-welding technique, will be most useful in other fabricating industries.

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Some Techniques in Galvanized-Strip Production

Full descriptions of the operation of the various types of continuous strip-galvanizing lines are available in the literature, and general information on the design of plant or on plant operation would be superfluous in this report. Some details are, however, given below of the more important aspects of the production of continuously hot-galvanized strip with special reference to the qualities used in motorcar manufacture. The type of basis steel used would, of course, vary depending on the forming requirements. Rimmed, balanced, and fully killed steels were used and even in the case of annealing in line (Sendzimir type) process some pre-annealed material was used as the feed material where necessary to produce grades suitable for very severe forming.

The extra-deep-drawing qualities which were supplied on demand were always aluminium-killed steels (to minimize ageing effects) which were subsequently temper rolled between ¼ and 1 per cent to avoid stretcher strain markings.

Bath Analysis and Control

The type of zinc used for strip galvanizing varies from plant to plant. In some cases the metal is almost entirely pre-alloyed (0.3 to 0.33 per cent Al) although small regular additions of a master alloy usually containing 10 per cent Al are necessary. In other cases virgin zinc was employed and additions of a zinc 10 per cent aluminium master alloy made to the bath.

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The extra-deep-drawing qualities which were supplied on demand were always aluminium-killed steels (to minimize ageing effects) which were subsequently temper rolled between ½ and 1 per cent to avoid stretcher strain markings.

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The type of zinc used for strip galvanizing varies from plant to plant. In some cases the metal is almost entirely pre-alloyed (0.3 to 0.33 per cent Al) although small regular additions of a master alloy usually containing 10 per cent Al are necessary. In other cases virgin zinc was employed and additions of a zinc 10 per cent aluminium master alloy made to the bath.

The normal bath compositions aimed at are 0.15 to 0.25 per cent Al, but the aluminium content is usually adjusted with reference to the type and

gauge of strip being processed. Thus baths with higher aluminium contents (up to 0.5 per cent) must be used for heavily worked steel and for heavy gauges (because of the lower line speed and hence increased immersion time) and for aluminium-killed steels. The lead content varies from about 0.2 to 0.35 per cent and the only other deliberate addition to the strip galvanizing bath is antimony (found in one case only).

For bath control regular determinations of the aluminium content of the bath were made but in the case of the Cook-Norteman type line, the standard practice was to analyze the coating for iron. For normal rimming steels (where a bath composition of 0.2 per cent Al was aimed at and maintained) the coating analyzed about 0.14 to 0.17 per cent Al.

Since the level of the nip in the rolls (and hence in the bath itself) is also important in the control of coating thickness, automatic devices were used in some cases to indicate the required additions (of both the slab and master alloy) with respect to the gauge of steel being processed and the desired coating weight.

Control of Coating Thickness

For the standard coatings which are produced, some use is being made of electronic scanning (Beta ray) gauges and these are at present in operation on four or five galvanizing lines. (The cost of these units was estimated to be about £20,000).

Apart from the thickness control, by gauging and by control of the bath composition and level, increasing attention is also being paid to roll design and roll conditioning techniques which have an obvious effect on uniformity of coating thickness. Rolls with spiral and concentric grooves are used, with perhaps slight preference being shown for the latter. Groove dressing operations are largely a matter of routine, but the use of spiral grooves permits automatic groove dressing by a travelling scraper. Although this technique has been considered by several plants, there was no evidence of it being in operation. For the rolls themselves, some firms preferred to use high purity iron (or dead mild steel), whereas others claimed advantages for heat treated carbon steels (up to about 0.25 per cent carbon) which were claimed to provide a more uniform surface condition. Some thought was being given to the use of rolls with protective coatings, particularly chromium plated rolls.

The normal limits for variation in coating thickness were stated to be ±10 per cent from edge to edge and ±20 per cent from back to front. In order to prevent edge build up the use of air blasts was being considered in some cases.

Differential and One-Side Coated Strip

Two techniques had been used for the production of differentially coated steels carrying about 0.15 oz. per sq. ft. on one side and 0.5 oz. per sq. ft. on the reverse side. The more common technique was to use a case hardened steel blade ($\frac{1}{16}$ in. radius) followed by an asbestos pressure pad on the "wiped" side. The alternative technique was to use as one of the exit pair of rolls, a smooth roll whose axis was above that of a standard grooved roll.

For the production of galvanized strip coated on one side only, various types of masking compounds had been used.

Neither sodium silicate (the more widely used compound) nor sodium aluminate were completely effective in preventing wetting of the "uncoated surface", and this surface usually required a subsequent scratch brushing treatment to remove local zinc. The net result was to produce a roughened surface, unacceptable for the skin panels of the motorcars for which it was intended. Greater success was claimed for a water soluble borate masking compound, but there was no evidence that material produced using this technique had been supplied to the motorcar industry. At the present time only a very limited amount of differentially coated material, and no one side coated hot dip galvanized strip, is being used.

Work is in progress on the development of superior masking compounds.

Finishing Treatments

To produce the matt "minimized spangle—satin finish" material required by some sections of the industry, steam jet cooling of the surface of the hot dip galvanized sheet, as it emerged from the galvanizing pot was the general practice. In one case, however, a dilute copper sulphate solution spray replaced the steam jet cooling.

The position of the steam pipe was adjustable for different gauges and different line speeds, and in the simplest arrangement the adjustment consisted simply of hooks positioned at 6 in. intervals on vertical support columns on either side of the moving strip. The horizontal jet spacing varied usually from $\frac{3}{4}$ to $1\frac{1}{2}$ in. The position of the jet pipe varied between about 5 to 15 ft. from the surface of the bath. In one case provision was made for movement of the jet pipe in the horizontal plane over a range of $\frac{3}{4}$ to 6 in. but in most cases it appeared that the jet/strip distance was about 1 to 2 in. Jets were usually inclined upwards at an angle of 45 to 60 deg., and it was claimed that poor results had been obtained when slots had been used.

It was general practice to have a long extension to the steam pipe on the exit side in order to maintain a reasonably uniform pressure in all the jets. Both saturated and dry steam were used, users of each claiming superiority over the other. A further refinement of the surface was obtained by passing the cool strip through grit-blasted rolls (usually 80 to 90 grit), a reduction of between $\frac{1}{4}$ and 1 per cent being given to the strip. In addition to the refine-

(*Continued in page* 643)

Determination of

THE DEEP-DRAWING CAPACITY OF ALUMINIUM AND ITS ALLOYS*

By ROBERT CHOPIN†

SUMMARY

THE author sets out to show that it is apparently impossible to determine the deep-drawing capacity of the various aluminium alloys by the customary properties and tests even in the most simple case of the cylinder.

He considers that among the current methods of investigation, only full-scale practical tests, made on several diameters and thicknesses will make it possible to plot curves, which, by interpolation, will provide useful information for deep drawers. In addition, he shows the influence of a number of parameters such as the thickness and condition of the metal, radius and drawing speed as well as the reasons for the choice of lubricant for the test.

KNOWLEDGE of the capacity of different materials for forming is necessary for determining the minimum number of operations required to produce a given component.

Mechanical tests and the various deep-drawing tests should provide a solution to this problem but it is generally agreed that the information that can be obtained from them has very limited application. With regard to deep drawing, in particular, interpretations of the figures provided prove very dangerous even in the drawing of cylindrical shells as soon as limits which are believed to be known are exceeded.

Many publications put forward figures on this subject, but these are not very exact and, in general, do not take into consideration the various influencing factors, notably thickness, exact dimensions and the nature of the material.

The author's tests are still not complete, but it seemed that the results obtained so far would be of interest.

Introduction

The capacity of a material for deep drawing is connected with the maximum amount of dimensional reduction‡ to which it can be subjected without cracking or tearing, during one or more drawing operations.

For cylindrical shells the maximum dimensional reduction‡ occurs on the outer contour of the blank, of which the initial length, F, becomes D (F and D being the respective diameters of the blank and the deep-drawn shell).

The capacity for deep drawing in the first operation is the ratio F/D which defines the dimensional reduction‡ suffered by the material in the operation under consideration.

In France, the inverse ratio D/F, called the "deep-drawing coefficient" is often used, as this is easier to use in calculations. The "reduction", calculated as a percentage from the expression $\frac{F - D}{F} \cdot 100$, may easily be deduced from the deep-drawing coefficient.

Experience has shown that the deep-drawing capacity depends on a number of factors which, *a priori* and not exclusively, are as follows :

- nature of the material ;
- diameter of the deep-drawn shell, D ;
- metal thickness, e ;
- radius of die mouth, R_M ;
- punch radius R_P ;
- diametral clearance between die and punch, 2J ;
- drawing speed, V ;
- nature of lubricant ;
- blankholder pressure, p ;
- temperature of blank and tool.

It was this complex function F/D = f (material, D, e, R_M R_P, J, V, p, lubricant, temperature . . .) that was studied experimentally.

General Test Conditions

The whole series of tests has been, or will be, carried out on the CIBLAT-FOUBERT hydraulic press at the Centre Technique de l'Aluminium in

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* A paper presented to a joint meeting of the International Deep Drawing Research Group and the Société Française de Métallurgie.

† Director : Centre Technique de l'Aluminium, Paris.

‡ The word "rétreint" used in the original French text is a term recently introduced by the French to express the idea of a "dimensional reduction."

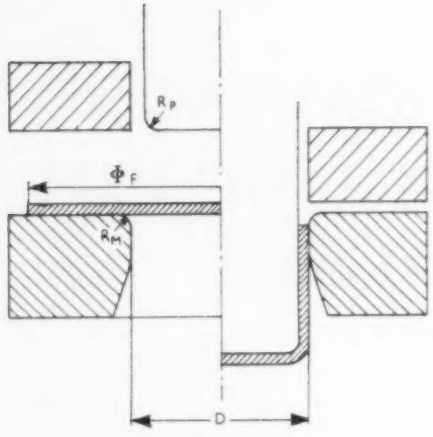


Fig. 1

Paris, the chief characteristics of which are as follows : maximum pressure of 200 tons at the ram, 70 tons at the blankholder, and, it should be noted, 40 tons on the third draw, stroke, 800 mm., drawing speed variable between 0.24 and 4 metres/minute ; the pressures developed at the punch and below the blankholder are measured by means of Richard recording manometers connected directly to the control cylinder of the press pistons.

The press tools are made of fine-grain cast iron in accordance with the diagram in Fig. 1, and the friction surfaces are wheel burnished to a surface finish having an RMS* of the order of 2.2 to 3.8 microns.

The sheets used have undergone the following measurements and tests : thickness, elastic limit, ultimate tensile stress, elongations at rupture (the values adopted being the mean of the figures obtained for longitudinal and transverse measurements), surface roughness, Erichsen test, Persoz test on 27- and 50-mm. diameters, KWI test and Jovignot test.

The experimental determination of the ratio F/D for each of the cases studied consists in discovering the largest diameter of blank that can be drawn using the optimum value of the blankholder pressure p.

* RMS = Root mean square.

Influence of the Nature of the Metal

Since all other variables are dependent on the following quantities : $D_P = 248$ mm ; $e = 1$ mm ; $R_M = 6$ $e = 6$ mm ; $R_P = 10$ $e = 10$ mm ; $J = O$; $V = 2$ m/min ; lubricant : tallow ; temperature : ambient, the deep-drawing capacity of the wrought light alloys are determined in these conditions. The results are summarized in Table I and Table II gives the compositions of the alloys used.

TABLE I

Classification	Alloy	Condition	F/D	D/F
1	A–G3	Annealed	2.08	0.48
2	A–U4G	Annealed	2.04	0.49
	A–G5	Annealed	2.04	0.49
	A5	¼-hard	2.04	0.49
5	A5	½-hard	2.02	0.495
6	A5	Annealed	1.98	0.505
	A–SG	Annealed	1.98	0.505
	A–SG	Solution treated	1.98	0.505
9	A–U4G	Solution treated	1.89	0.53
10	A–G1	Annealed	1.87	0.535

Table I calls for two comments :

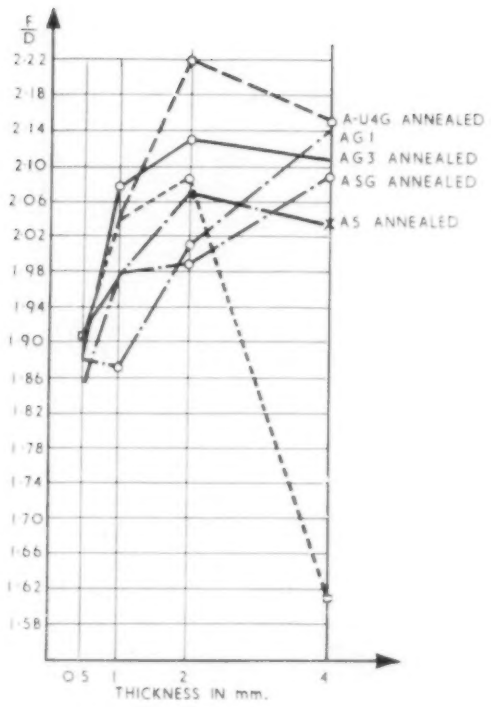
In the case of aluminium (A5) it is found that the ¼-hard and ½-hard conditions permit better deep-drawing ratios than the annealed condition.

This observation, which is well known to deep drawers, can be explained by the fact that the A5 material, in the annealed condition, stands up well to dimensional reduction and is therefore a good deep-drawing material; however, its low ultimate tensile strength facilitates fracture of the component under the pressure required for deep drawing a large blank. The increased difficulty of reducing dimensionally a slight work-hardened (¼-hard) metal is more than compensated by the increased tensile strength which reduces the risk of fracture. In passing once more to a harder grade of metal (½-hard), the difficulty of dimensional reduction increases and reduces the deep-drawing capacity which, however, is still better than that of the annealed metal.

The heat-treatable alloys, A–SG and A–U4G, deep drawn in the solution-treated condition 15 minutes after heat treatment, give the following results in relation to the normal condition :

TABLE II—*Alloy designations quoted in the text refer to French materials of the following compositions:—*

	Al	Fe	Si	Cu	Zn	Mg	Mn	Ti
A5	99.5							
A–G1	rem	≤0.4	≤0.3	≤0.1	≤0.1	0.8–1.7	≤0.7	—
A–G3	rem	≤0.4	≤0.3	≤0.1	≤0.1	2.5–3.7	0.2–1	—
A–G5	rem	≤0.4	≤0.3	≤0.1	≤0.1	4.5–5.8	0.2–1	—
A–SG	rem	≤0.5	0.8–1.5	≤0.1	≤0.1	0.7–1.3	≤1	—
A–U4G	rem	≤0.5	0.3–0.8	3.5–4.5	≤0.1	0.5–1	0.3–0.8	≤0.2



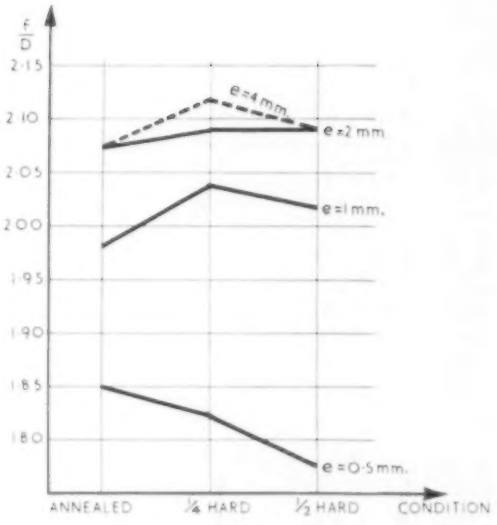


Fig. 2 (left)

●

Fig. 3 (above)

with A–SG the same ratio can be obtained as in the annealed condition ;

with A–U4G, this ratio is reduced from 2.04 to 1.89, representing a large drop in the deep-drawing capacity.

Influence of Diameter of the Drawn Shell

Experience has confirmed that the diameter D of the drawn shell has an influence on the deep-drawing capacity F/D and that this influence varies also as a function of the metal thickness : this has not yet been shown by the tests, limited so far to D = 248 ; tests in progress deal with deep-drawing conditions for D = 100 mm. and D = 400 mm.

Influence of Metal Thickness

This influence has been investigated using four different metal thicknesses : e = 0.5, 1, 2 and 4 mm. The influence of metal thickness varies with the nature of the metal in such a way that the classification indicated in Table I also varies with metal thickness.

The results of the tests are summarized in Table III which gives the deep-drawing capacity F/D as a function of the nature and thickness of the metal for the same relative radii R_M = 6e and R_P = 10e.

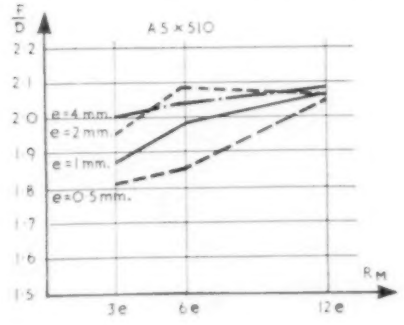


Fig. 4 (left)

●

Fig. 5 (right)

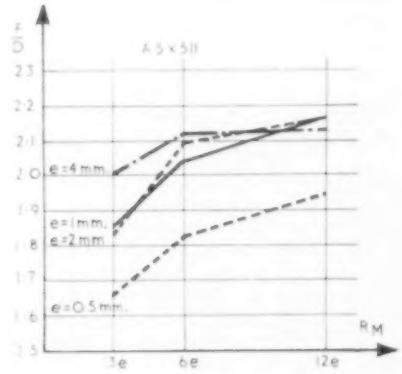


TABLE III

		Thickness e, mm. 0.5		1		2		4	
		Classn.	F/D	Classn.	F/D	Classn.	F/D	Classn.	F/D
A–G3	annealed	3	1.89	1	2.08	2	2.13	4	2.11
A–U4G	annealed	5	1.87	2	2.04	1	2.22	1	2.11
A–G5	annealed	1	1.91	2	2.04	3	2.09	8	1.61
A5	½-hard	7	1.83	2	2.04	3	2.09	3	2.12
A5	½-hard	9	1.75	5	2.02	3	2.09	5	2.09
A5	annealed	6	1.85	6	1.98	6	2.07	7	2.03
A–SG	annealed	1	1.91	6	1.98	8	1.99	5	2.09
A–SG	solution treated	8	1.81	6	1.98	8	1.99	—	—
A–U4G	solution treated	10	1.69	9	1.89	10	1.73	—	—
A–G1	annealed	4	1.88	10	1.87	7	2.01	2	2.14

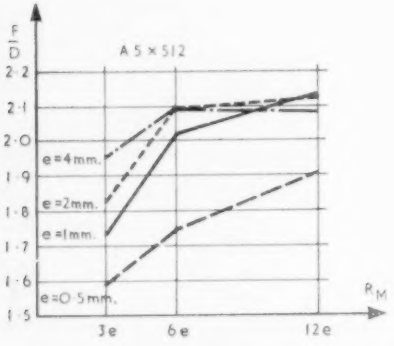
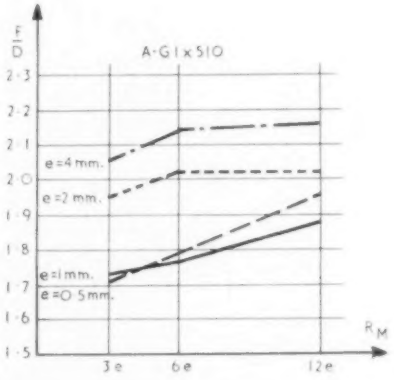


Fig. 6 (left)

Fig. 7 (right)



These values have been reproduced in the form of a graph (Fig. 2) from which it is possible to draw the following tentative conclusions :

The classification of the different light alloys according to their capacity for deep drawing varies according to sheet thickness ;

in identical deep-drawing conditions, deep-drawing capacity increases with metal thickness, at least up to 2 mm. Beyond this thickness, for certain alloys : A–U4G annealed, A–G3, A5 annealed and, in particular, A–G5, the capacity for deep drawing passes through a maximum for a certain thickness, the value of which depends upon the nature of the material.

In particular, it can be said that if the capacity for deep drawing of A5 increases with the thickness of the metal, the classification as a function of the degree of hardness found for the 0.5-mm. thick material is the opposite of that recorded for greater thicknesses. This is at present an anomaly.

With regard to alloys that are deep drawn in the solution-treated condition, investigations on the various thicknesses confirm the results already

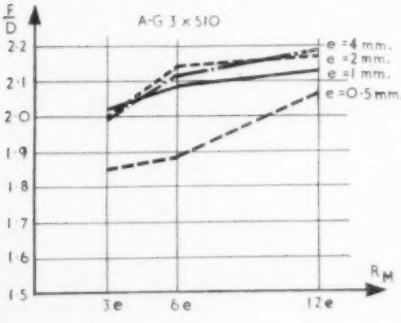
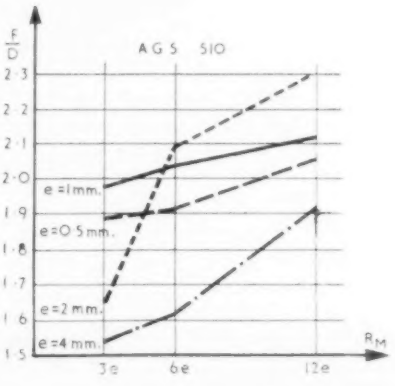


Fig. 8 (left)

Fig. 9 (right)



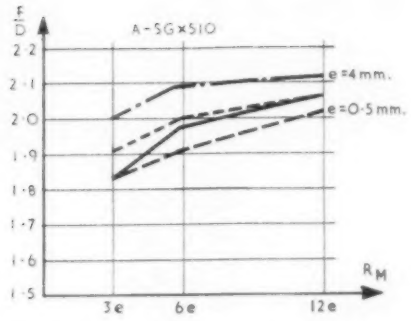
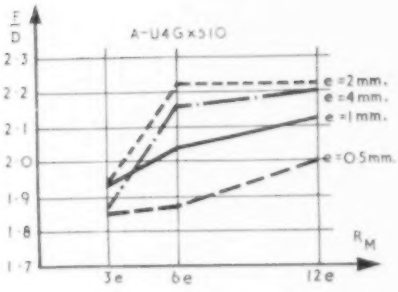


Fig. 10 (left)

Fig. 11 (right)



quoted in Table I : A–SG remains a good material for deep drawing several months after solution treatment and A–U4G, which can only be deep drawn within a very short period of solution treatment (15 to 30 minutes) becomes much less suitable for deep drawing than in the annealed condition.

Influence of Die Radius

The radius over which the metal moves into the die has a definite influence on deep drawing. Too small a radius stretches the material and increases its hardness ; too large a radius makes it impossible to keep the sheet under the pressure of the blankholder and favours the formation of wrinkles during and at the end of the operation.

Tests were carried out with die radius values of 3, 6 and 12 times the thickness of the sheet and the results obtained have been plotted (Figs. 4 to 11). Here also, it can be seen that for the alloys under consideration, at least, deep-drawing capacity always increases on passing from a die radius of 3e to a die radius of 6e and still increases, in general, although to a lesser degree, on passing to a radius of 12e. Only A5–½H, 4 mm. thick, A–G1, 2 mm. thick and A–U4G, 2 mm. thick, have effectively equal cylindrical deep-drawing capacities with die radii of 6 and 12 times the thickness.

For these particular cases it may therefore be assumed that the maximum deep-drawing capacity would be obtained for a die radius of about 10e.

In the general case the optimum die radius seems to be greater than 12 times the sheet thickness and supplementary tests to determine this value are envisaged for the testing programme. But here and now it is recommended that a die radius of 10 times the sheet thickness for difficult deep-drawing operations in alumium and its alloys is used.

Influence of Punch Radius

All the tests described here were made with a radius on the head of the punch equal to 10 times the thickness of the sheet ; the effect of a different value on the deep-drawing capacity will not be investigated systematically until later.

However, certain special tests, conducted with a punch radius equal to half the diameter of the deep-drawn shell (hemisphere) have shown that it was possible to obtain with some alloys (notably A–G3 and A–G5) a drawing capacity F/D equal to or greater than 2.

Influence of Clearance

Most of our tests have been carried out with a diametrical clearance 2J between the sides of the die and the punch exactly equal to the space required for the sheet, *i.e.* there was no supplementary clearance, j, defined by :

$$\varnothing_M = \varnothing_P + 2e + 2\frac{j}{e}$$

and expressed in per cent sheet thickness.

However, the deplorable results obtained with j = O on 4-mm. thick sheet led us at once to carry out tests using the minimum clearance that seemed necessary for this thickness, *i.e.* j = 8 per cent.

Other supplementary tests, as well as experience of some special cases, led us to think that the deep-drawing capacity should increase with the clearance j up to a value which still remains to be determined but which should lie between 10 and 20 per cent of the thickness of the sheet. A later systematic investigation will make it possible to confirm this supposition.

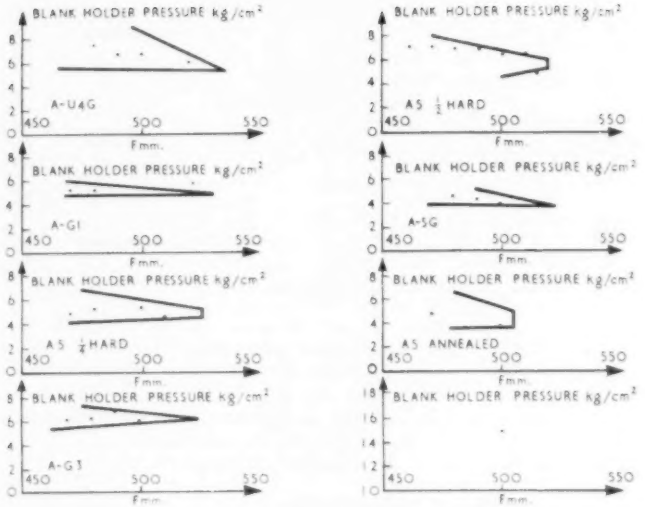
Influence of Drawing Speed

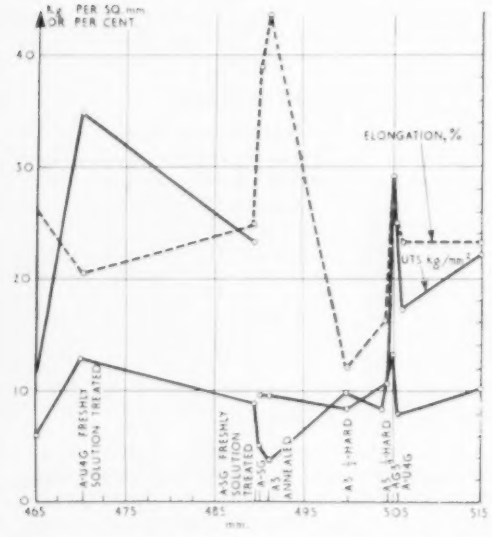
Some people claim that for a given shell a larger blank can be drawn on a hydraulic press than on a mechanical press because of the lower drawing speed, but it is necessary to take into consideration certain elements that are difficult to evaluate such as the variation of this speed during the course of the operation and the variation of the application of stress to the blankholder as well as the variation of the initial speed of the punch.

We wished to consider as a valid test only the variation of the drawing capacity as a function of the speed of hydraulic presses. With the machine used, which has a working speed variable by stages from 0.24 to 4 metres per minute, it was not possible to establish a variation in the drawing capacity other than that attributed to the inevitable scatter of experimental results.

Fig. 12 (right)

Fig. 13 (below)





According to a few tests carried out in very special conditions, the speed, in all, had no influence on the deep-drawing capacity between 0.24 and 4 metres per minute.

Influence of Lubricant

All the tests described were carried out with the blanks lubricated with tallow which was applied by hand; this lubricant was chosen as reference because it gives excellent results and offers a number of secondary advantages: availability in a suitable quality, ease of degreasing with chlorinated solvents, relative ease of application, neutrality towards light alloys.

A number of comparative tests have been carried out with other lubricants and it has been found that some commercial products are superior to tallow as a lubricant for deep drawing. It is wise, however, to consider that when a shell cannot be drawn using tallow, the margin provided by special lubricants is generally insufficient for fabrication on a mass-production scale.

Influence of Temperature

Increase in the temperature of the metal favours deep drawing because it increases plasticity and facilitates dimensional reduction. However, it is only the annular part of the blank, situated underneath the blankholder, that benefits from such increased plasticity. The centre, beneath the head of the punch should remain cold to avoid loss in tensile strength.

The tests were therefore carried out using a die and blankholder heated to about 250° C. and a cooled punch.

These tests have shown, for example, that for a thickness of 4 mm., the deep-drawing capacities of A–G3 and A–G5, which are 2.11 and 1.61 respectively at ambient temperatures, increase on heating to a common value of 2.26. This result shows an appreciable increase in the deep-drawing capacity with temperature, particularly in the case of A–G5.

Influence of Blankholder Pressure

In each test the specific pressure, p, effectively applied to the surface of the metal situated underneath the blankholder was calculated and the pressure adjusted so as to obtain neither folds nor tearing. By plotting the values of p and F which

(*Continued in page* 643)

Determination of the Deep-Drawing Capacity of Aluminium and its Alloys

(*Continued from page* 642)

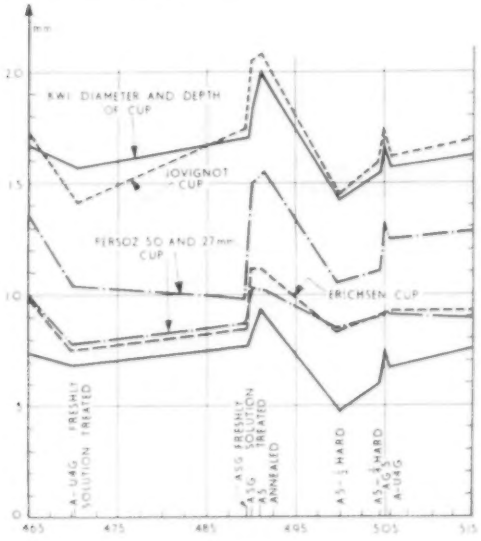


Fig. 14

gave good deep-drawn shells, diagrams such as those shown in Fig. 12 were obtained (relating to sheets with a thickness of 4 mm.)

It can be seen that the latitude for pressure adjustment at the blankholder diminishes as the difficulty of deep drawing increases, and at the limiting size of blank that can be drawn the specific pressure of the blankholder tends towards a definite value.

Relation between the Practical Tests and Traditional Tests

An attempt has been made to correlate the deep-drawing capacity found in the practical tests with the mechanical properties and cupping tests made on various sheets.

Figs. 13 and 14 show the graphs obtained with sheet 1 mm. thick. It can be seen from Fig. 13 that it is not the alloy with the best elongation (annealed A5), nor that with the best ultimate tensile strength (A–U4G immediately after solution treatment), nor the largest nor the smallest elastic limit, which is the best deep-drawing alloy.

Similarly, from Fig. 14, it may be seen that the best material for deep drawing is not that which gives the best results in the traditional tests. It should also be noted, from this graph, that A5–$\frac{1}{2}$H which, according to the tests should be inferior to annealed A5 or A–SG, is actually superior.

In a word, there is no apparent connexion between the actual deep-drawing capacity and the information provided by measurement of the mechanical properties and examination of the results of the various cupping tests.

Conclusions

These few practical results relating to one diameter only and four thicknesses, show that it seems to be impossible to determine the deep-drawing capacity of an aluminium alloy as a function of the mechanical properties and the results of traditional tests.

They show, moreover, the influence of several parameters, such as thickness and condition of the material, properties of the material and type of equipment (influence of drawing speed) and choice of lubricant.

They seem to be difficult to apply unless they are related to a series of tests made with two different diameters, 100 and 400 mm., which will make it possible to trace curves for practical use. These tests are now in progress.

They will be followed by tests of maximum dimensional reduction, by two different methods, on the shells obtained in the course of the tests described above. It is thought that it will be possible to determine the maximum drawing capacity of the different alloys, without intermediate annealing, and the best depth for the successive draws to obtain this result.

The Use of Galvanized Strip in Automobile Manufacture in the U.S.A.

(*Continued from page* 636)

ment of the surface this treatment was also intended to eliminate the fluting tendency.

All hot galvanized strip supplied to the motorcar industry was subsequently oiled. Strip supplied to other industries was, however, invariably given a chromate finish either in sodium dichromate/sulphuric acid solutions, straight chromic acid solutions, or in chromate solutions which produced deposits rather than conversion-type coatings. All these were in use.

"WELDING ENGINEERING 1962"

THIS is the title of the first exhibition to be organized by the Institute of Welding; it will be held at Buxton, May 2 to 4, 1962, to coincide with the Institute's Spring Conference. Further details and applications for space should be addressed to the Exhibition Dept., Institute of Welding, 54 Princes Gate, London, S.W.7.

PRODUCING A CLICKER ASSEMBLY for "One-Arm Bandits"

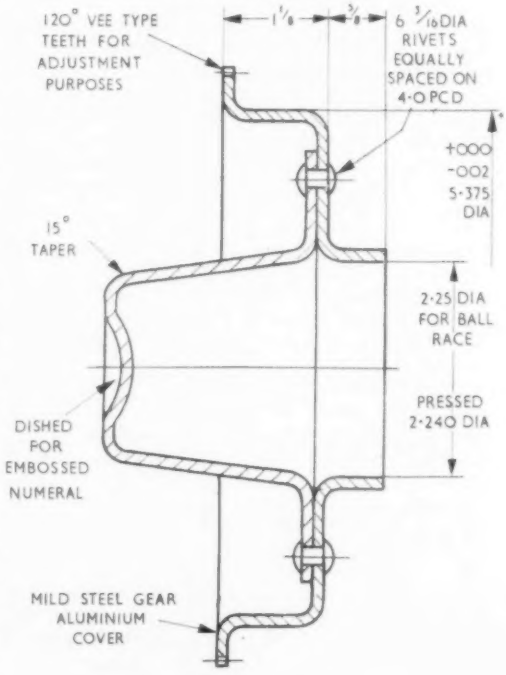
By "TARENTFORD"

"ONE-ARM BANDITS" are by no means new to Britain though it has taken many years to legalize their installation in clubs throughout the country. The mechanism of one of these machines is both elaborate and ingenious and presswork features a great deal as this method of production is both speedy and economical. Generally the rough treatment to which the machines are subjected makes it essential to use steel parts rather than to rely entirely on cast pieces except where little wear occurs. The tooling of these pressed parts is thus comparatively elaborate especially as many of them are applicable to several different machines, and a production schedule of five to ten thousand a week is quite common across the Atlantic where the number now in use must approach a million or so.

The apparently simple looking pair of details, shown in Fig. 1, comprises a steel clicker drum riveted to an aluminium cover, the latter material was chosen because lightness was an important factor in this instance, and the drum was afterwards ground in the bore to provide a location for a ballrace, while the cover, in addition to making a site for a small amount of grease, also served as a setting medium for the machine as numerals were stamped on the small dishing made in the bottom.

The production of the drum presented several unusual features though all the tools more or less followed orthodox design methods. Fig. 2 illustrates the initial stage in the production which blanks, pierces, draws and extrudes the boss for the ballrace; the inner diameter is drawn approximately 0.01 in. smaller than the race to provide material for a subsequent internal grinding operation, but as nothing is secured to the front face of this boss a trimming process is not included in the layout. Because three details fit over each other in the lower bolster, the item "A" is a heavy and thick detail into which the blanking die "B" is recessed, and a further bore at the bottom of the clearance recess is necessary to make a location for the extrusion and piercing punch "F". Over this item slides the draw punch "E" and again over this member is the pad "D", giving a setting when the lower tool reaches the bottom of the stroke. Control of these items is achieved with the aid of the usual pins "G" and "H" passing up through the bolster, and they are operated by heavy-duty springs and plates assembled in the housing "N". These plates are drilled to clear the appropriate pins and

Fig. 1.—Lightness coupled with concentricity was the important feature of this assembly, and to reduce weight, aluminium was used for the cover. Although accurate pressing was essential, internal grinding was necessary for the ball-race diameter


120° VEE TYPE TEETH FOR ADJUSTMENT PURPOSES
1 1/8
3/8
6 3/16 DIA RIVETS EQUALLY SPACED ON 4·0 PCD
+000 -002 5·375 DIA
15° TAPER
2·25 DIA FOR BALL RACE
PRESSED 2·240 DIA
DISHED FOR EMBOSSED NUMERAL
MILD STEEL GEAR ALUMINIUM COVER

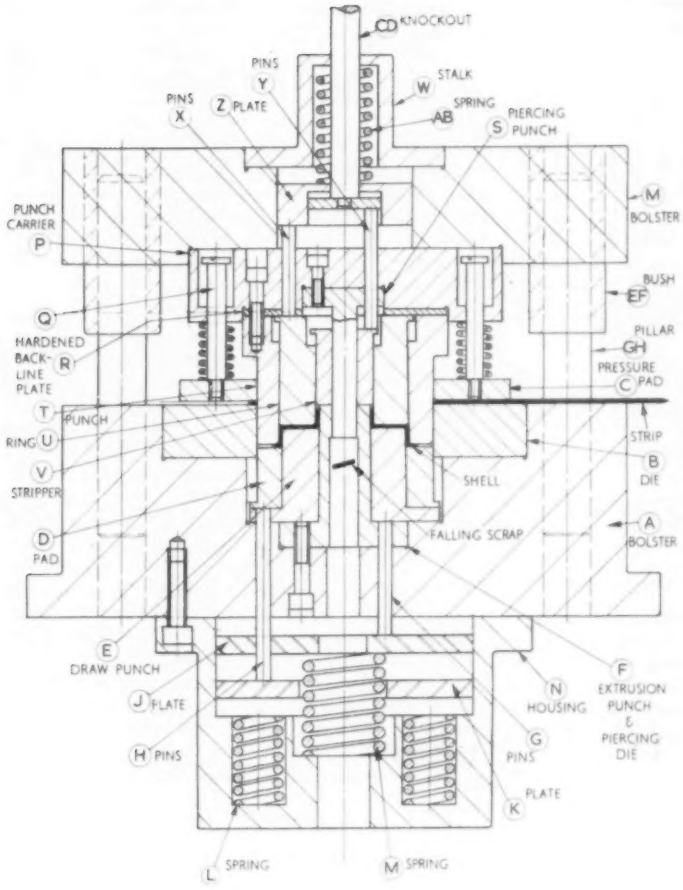


Fig. 2.—This tool produces the major portion of the work on the gear detail, and although apparently complex, all the parts are finished by simple rotary grinding operations, each item being accurately located by means of the recess and spigot method

spring to give an independent movement to the pad and drawing punch. A generous clearing hole is also drilled through the bolster, plate and housing to ensure the scrap slug can fall without obstruction. A mechanical feeding mechanism is employed for the strip which is received at the press in rolls.

The upper tool is somewhat comparable with the lower assembly, only two details slide inside the blanking punch instead of over the central member. After blanking, the punch "T" performs the dual role of drawing the shell and the material is controlled throughout the stroke by this detail and the lower pad "D". Piercing occurs simultaneously with the blanking operation and the extrusion is accomplished with the aid of the ring "U", while the stripper "V" which surrounds the central piercing punch "S" ensures the drawn part does not adhere to the ring as the press ram rises. Again the operation of details "U" and "V" is effected by two pins though on this occasion only one is spring operated while the other is arrested by the action of the knockout "CD" meeting an obstruction in the machine slide.

Careful control of the material during the working of this operation is an essential factor and except when the extrusion leaves the vicinity of the stripper and extrusion punch, a predetermined pressure is always exerted. The location of all the parts by means of a recess is important as this method gives greater accuracy than relying on a tool fitter setting each detail separately and dowelling them in position, and the inclusion of pillars and bushes aids quick setting on a press bed as well as securing correct alignment, with the top and bottom members.

The next operation Fig. 3, consists of cutting the teeth on the rim of the shell. Slight distortion occurs in a process of this nature and cutting these teeth overcomes the necessity of a trimming stage to improve the shell rim. A location is secured from the outside diameter and the usual sliding stripper "C" is used for this purpose. This item however, differs from the normal design in that teeth are also machined on the periphery to match those already in the cutting die "B", and again this member is located by a recess turned in the lower bolster "A". During the production of this press tool a small milling cutter was made for machining the vee teeth on the stripper, and was provided with a Morse taper shank and used directly in the workhead of a milling machine. The outside diameter was restricted to clear the flange turned on the stripping detail, shown in the drawing. Cutting the punch

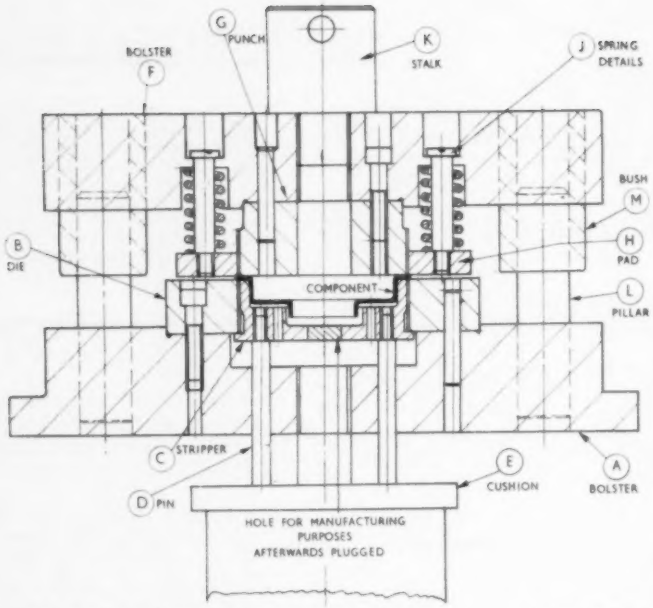


Fig. 3.—The trimming tool incorporates the gear teeth round the periphery and this demands accuracy during the manufacturing stages somewhat above the normal requirements of such a tool. In this case the making of a cutter for milling the teeth is of prime importance in its construction, and enables the mating pieces to fit together to give the necessary sliding fits

teeth was also achieved in a similar way using a dividing head for location and indexing purposes. The machining of a slotting tool with four or five teeth carried out with this cutter meant that both the die "B" and stripper pad "H" were accurately machined to correspond with the punch and lower pad.

The small ring of scrap is left round the shell when the latter is removed from the tool, and the operation is assisted by a blast of air through the cushion and the series of holes in the stripper "C". A hole is always a useful feature to add to a circular detail and the stripper has this means of location, but the insertion of a brass plug is necessary to ensure that all the air is acting on the component during the ejection process and so causes it to leave the location diameter. Careful heat treatment is essential with tools of this form and the material used for both the punch and die was Kayser Ellison 637 oil hardening non-shrinking tool-steel which needed a temperature of 780 to 800° C., with a quench in oil.

The final operation on this item consists of punching the rivet holes that secure it to the cover detail and the tool follows conventional lines utilizing the outside diameter as a location medium. The locating ring "B" houses the six die inserts "C" and again the centre hole is plugged to allow the air blast to exert full pressure on the shell and so eject it from the cavity. Inclining the press 45 deg. helps with tools of this description as it enables shells of this size to fall away without a further handling.

The introduction of a hardened steel plate "H"

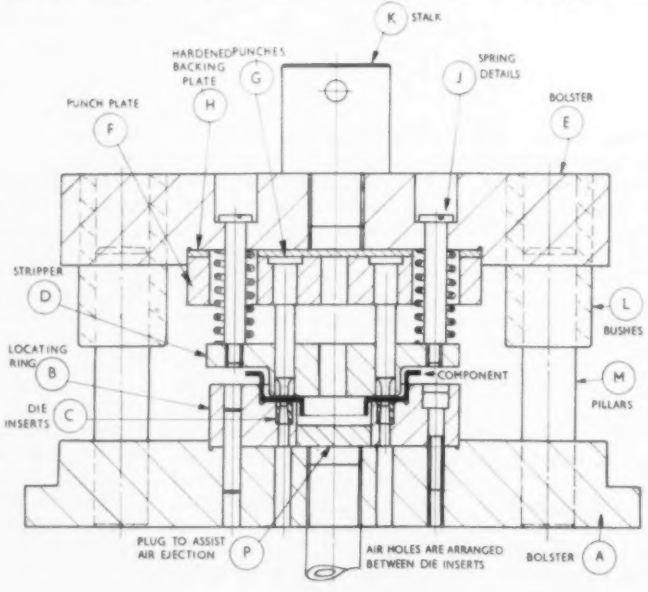


Fig. 4.—An orthodox piercing tool locating the component from the drum diameter is seen here for punching the rivet holes. While hand loading is employed, removal is carried out by means of an air blast

behind the punch heads is essential to prevent the bolster from becoming marked and the punches are themselves retained by a thick punch plate "F". The placing of both pillars at the rear of the tool is an asset because this ensures the loading area is not obstructed.

Because of the need to produce a series of different covers differing only very slightly in detail, a separate blanking tool is used for these blanks utilizing a strip feeding mechanism after the material has passed from a coil through straightening rolls.

The tool shown in Fig. 5 is thus of conventional design although again the opportunity is taken to recess both the punch "D" and the die "B" into their respective bolsters. This die is somewhat more massive than previous examples due to the large diameter bore made necessary by the blank, and it is a wise precaution on these occasions to also increase the die thickness above the usual 1 in., generally deemed the best dimension to assume for a die of this type. The strip is held in close contact with the die surface by the action of the pad "C" and this member is controlled by six heavy-duty springs arranged round the punch "D". The press for this work had a 2 in. stroke and was set to produce some 40 blanks a minute.

Fig. 6 illustrates a tool for use on a double-action press for producing the deep shell from blanks made in the previous tool, but as a series of different details are necessary each requiring a rearrangement of the letters embossed in the recess made on the floor of this article, the punch nose is made detachable and the lower ejector is also easily replaced.

A die producing a deep taper always requires adequate support in order to overcome the severe bursting pressure exerted when the punch descends,

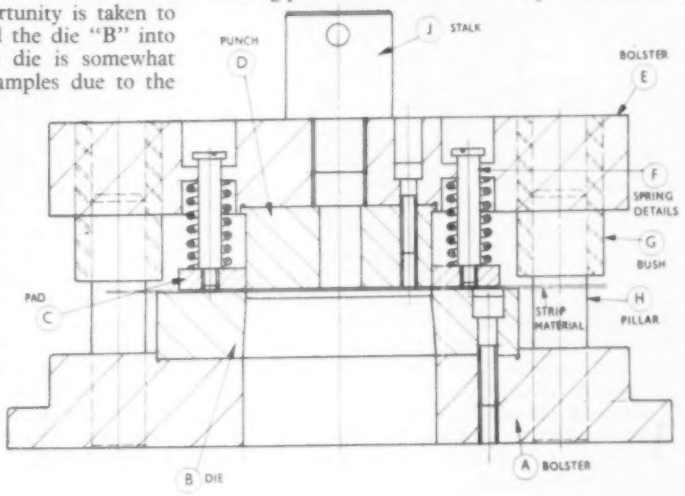


Fig. 5.—The initial operation on the cover was the production of a simple blank; an operation made necessary because of the variety of details of similar shape and size but having different markings during the final drawing operation

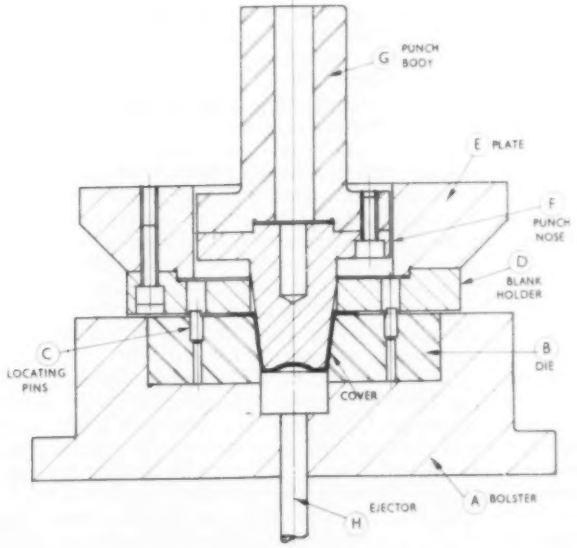


Fig. 6.—The double-action tool for producing the tapered shell. The substitution of the punch and ejector simplified the problem of various markings on the lower surface

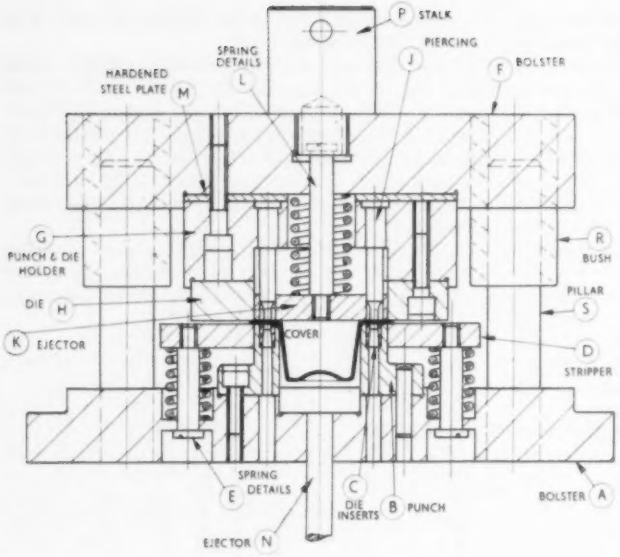


Fig. 7.—Piercing and trimming of the cover is accomplished in this tool. Though the trimming stage is not strictly essential, it did remove a section of unwanted material without the necessity of further handling of each article

and for that reason the die "B" is sunk completely into the steel bolster "A". The latter is made from that material because of the economy achieved in using a billet sawn from a bar rather than relying on a cast detail in spite of the fact that only a simple pattern is necessary.

Simplicity when choosing the location is one of the chief points to consider in the design of a press tool and the arrangement of a series of silver steel pins on a P.C.D. rather than relying on a shallow recess accurately ground on the top surface of the die, is often a preferable way to position a component. Such a location does not allow dirt and minute chippings to adhere to the floor of the location and so cause difficulties when the blank holder "D" descends. These pins "C" are driven to the bottom of a reamed hole with the remainder simply drilled for ejection purposes when required. This method overcomes the problem of the pins being accidentally pushed flush with the die surface and making it essential to remove the tool from the press bed before they can be again restored to their correct position. A series of clearing holes is also drilled in the blank-holder as these pins will necessarily stand above the circular blank.

The case hardening of a blank-holder on the surface which contacts the blank is advisable as the burr thrown up when severing the material coupled with the possibility of chips being pressed on the material, can cause damage and repeated regrinding of the face. The ejector "H" performs a dual role in that it lifts the shell from the tapered die and though not completely removing it from this bore, it does make the final removal an easy operation and no sticking can occur. If the ejector only lifts a short distance the loading of the next shell is not impeded and the blank-holder will ensure it is pushed down on the die surface.

Trimming the outside diameter and piercing the same number of holes on the pitch circle is accomplished in the next tool shown in Fig. 7 and the location is taken from the top diameter of the tapered portion of this shell. The risk of a shell not properly seating is thus avoided.

This tool has the punch set into the lower bolster while the trimming die is set on an extended punch holder "G", but there is just sufficient room to arrange the piercing die inserts in the punch "B" without running the risk of the latter cracking during production. The importance of scrap removal is stressed with tools of this type and the thin ring is returned to surround the shell when the press rises, accomplished by the the stripper ring "D" which is heavily spring-loaded and arranged to finally leave the stripper in the top position flush with the punch face.

The upper member in addition to having the die "H" included in the design, also accommodates the piercing punches and an ejector to prevent a finished shell from adhering to these details. While a shell left in the lower tool is generally visible to an operator, an item that adheres to the punches and rises with the motion of the ram, is not often immediately noticed and the pressing of a further part can have disastrous results to both sections of a tool. A heavy coiled spring is thus arranged inside the punch holder and this will ensure the shell stays on the surface of the lower tool.

The provision of a hardened punch plate behind the heads of the punches "J" follows the design adopted in Fig. 4 and is a refinement which costs very little to make because $\frac{1}{2}$-in. thick gauge plate, a material that readily hardens is ideal for such occasions, and it need only fit easily in the recess. The drilling of clearing holes for the screws that

(*Continued in page* 674)

Quantitative Assessment of

DEEP DRAWING and STRETCH-FORMING QUALITIES*—I

By J. C. WRIGHT, B.Sc., Ph.D., A.I.M., A.C.T. (Birm.)†

FOR more than twenty-five years there has been considerable interest in attempts to assess the deep-drawing and stretch-forming qualities of sheet materials without resorting to full-scale press trials. In the last ten years the interest has intensified very considerably, particularly in attempts to assess deep-drawing and stretch-forming ability in a quantitative manner. The degree to which these efforts have been successful in developing methods of correctly assessing the performance of sheet prior to pressing is a subject which has been, and still is, fiercely debated. Undoubtedly, the success of some tests has been exaggerated. Equally, tests have been unduly criticized for not achieving more than their originators ever intended. Much of the argument is resolved when it is realized that confusion exists over the terminology of pressing operations and over the deformation mechanisms operating in the various types of operations. The object of this account is to review particularly those tests which attempt to produce useful quantitative data upon which sheet material may be assessed for presswork and to discuss the limitations of the tests. To do this, it is necessary to define the type of press operations to which the tests may be applied. In this account, the press operations of interest are those lying between the two extremes of deep drawing and stretch-forming. The modes of deformation of the sheet in these two operations are quite different and the realization of this fact has done much to reduce the confusion over why a particular test correlated well with only certain types of press operations.

At the one extreme, deep drawing may be explained by reference to Figs. 1 and 2. The essentials are that the blank is held between the blankholder and the die with enough pressure between the two to prevent the blank from wrinkling as it is drawn into the die. The pressure necessary

* This article is based on two lectures included in a special course on "The Metallurgy of Deep Drawing and Pressing", held at the Department of Metallurgy, Birmingham College of Advanced Technology.

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Fig. 1.—A schematic representation of pure deep drawing (Whiteley [41])

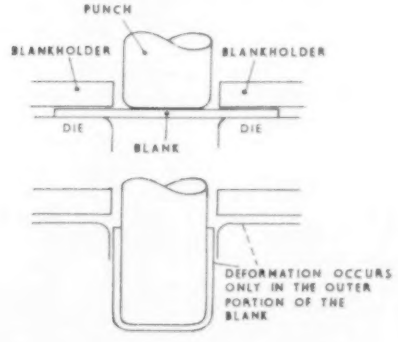
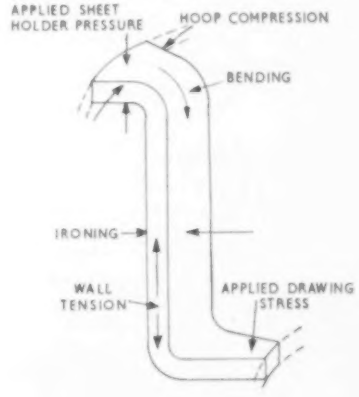
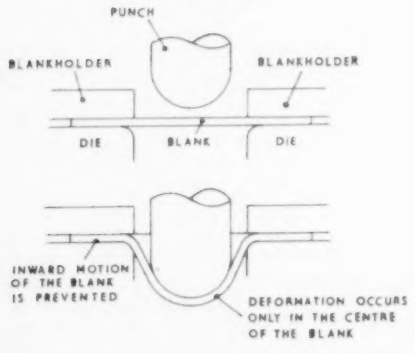


Fig. 2.—Sketch showing applied and resultant stresses in a partially deep-drawn segment



to prevent wrinkling is small compared with the punch pressure necessary to draw the blank into the die. Furthermore, the profile of the punch nose is such that the part of the blank in contact with it at the start of the operation is not deformed. To ensure this, the punch profile radius must be small compared with the punch diameter. Thus, in the extreme form of deep drawing, no stretching takes place in the sheet situated over the punch nose. The drawing stress is transmitted to the sheet through the punch which pushes the blank through the die. The material is drawn into the wall of the cup from the flange under the blankholder; the flange is reduced in circumference and in so doing a hoop compression stress is generated in the part of the blank which is still in the blankholder. The blankholder pressure restrains the tendency of the flange to wrinkle in an attempt to relieve the hoop compressional stress. Nevertheless, a more uniform thickening of the blank does take place, particularly as each part of it leaves the influence of the blankholder and crowds into the die mouth. In theory, this thickening could be prevented if the lead into the die mouth was square but this is impracticable. As shown in Fig. 2, the blank undergoes tensional stress in the cup wall between the punch and the die, bending stresses as it leaves the blankholder and unbending when it becomes part of the cup wall; and hoop compressional and normal stresses while under the blankholder. In addition, unless the thickness of the blank, as it becomes part of the cup wall, is equal to or less than the gap between the punch and the die, the cup wall will be subjected to an ironing effect produced by tension in the direction of drawing and compression between the punch and die. If no reduction of wall thickness is to take place, a clearance between the punch and the die of as much as 40 per cent in excess of the original sheet thickness may be required to allow for the thickening of the blank as it crowds into the die mouth.

Fig. 3.—A schematic representation of stretch-forming (Whiteley [41])



The other extreme type of pressing, stretch-forming is illustrated in Fig. 3. In this case, the blank is locked in the blankholder and cannot be drawn in, but the punch profile is of such a form that the material can be deformed by stretching over the punch profile. The blankholder pressure is very much higher than in deep drawing and no hoop compression stress is created in the blank. Most of the deformation takes place over the nose of the punch whereas, theoretically, in pure deep drawing there is no deformation over the flat nose of the punch.

Between these two extremes lies a range of pressing operations which combine more or less of the deformation characteristics of both and the majority of commercial pressing operations are achieved by neither pure deep drawing nor pure stretch-forming. Similarly, tests which attempt to simulate pressing operations also incorporate deformation characteristics of deep drawing or stretch-forming or a mixture of both. It is not difficult to get satisfactory correlation between test results and press-shop results when the test and press operation are both almost entirely deep drawing in nature or both stretch-forming. The greatest difficulty arises when the press operation involves a rather indefinite mixture of deep drawing and pressing. No test has yet been devised which can incorporate both the deep-drawing aspect and the stretch-forming aspect in precisely controlled amounts. Even if this was possible, there is still the difficulty of assessing a given pressing in terms of the relative importance of deep drawing and stretch-forming so that reasonable simulation is achieved. Nevertheless, several types of simulative tests have been developed which incorporate one or more of the mechanisms operating in deep drawing and stretch-forming. Provided their fields of application and their limitations are realized, the simulative tests can be very useful, though rarely perfect, at present, in assessing sheet performance.

The alternative to developing closely simulative tests is to examine those mechanical properties of sheets which can be associated with satisfactory deep drawing or satisfactory stretch-forming. Considerable developments have been made in interpreting such non-simulative testing in the last ten years arising from a better knowledge of the fundamental mechanisms involved in deep drawing and stretch-forming.

The methods of assessing the likely performance of sheet metal in press work fall into three main categories; metallurgical quality tests such as metallography, chemical and X-ray crystallographic analysis; quantitative non-simulative tests such as hardness, tensile testing, and bulge testing; and quantitative simulative tests such as the Erichsen or Olsen cupping tests, Swift or Erichsen cup-drawing tests, hole-expanding, wedge-drawing and bend

tests. The bulk of this account is concerned with assessing the extent to which test procedures represent sheet behaviour in commercial presswork and must therefore concentrate largely on quantitative tests. Nevertheless, tests of metallurgical quality should be introduced briefly.

Tests of General Metallurgical Quality

The development and assessment of the general metallurgical quality of sheet destined for the press shop has been dealt with in detail by *Jevons*[1]. Generally speaking, such quality tests are of prime concern to the sheet producer as part of his production quality control or to the user in investigating unexpected failure to produce satisfactory pressings. Such tests are not sufficiently discriminating for predicting press performance on a routine basis, apart from which, most of the tests are rather lengthy. For instance, chemical analysis is of considerable value to the sheet producer in both day-to-day and long-term quality control but the user should not need to use chemical analysis until either simpler mechanical tests or unsatisfactory press-shop performance has revealed faulty material. As examples of general correlations which are possible, *Pearce* [2] has pointed out that extra-deep-drawing-quality rimming steel usually contains about 0.05 per cent carbon, stabilized steel slightly more and a limit of 0.08 per cent carbon is desirable for pressings which later undergo high-speed welding. An unusually low manganese content can result in low tenacity in a steel with otherwise good properties and a relatively high sulphur content can be a reason for very fine grain-size which gives an exaggerated yield point elongation and consequently marked stretcher-strain markings. As an example of analytical control in non-ferrous press-work, zinc contents in excess of 36 per cent in brass are likely to introduce severe deep-drawing problems due to the presence of the beta-phase.

Similarly, metallographic examination is a powerful tool in "post-mortem" examination of failed pressings and useful in quality control in assessing grain-size, segregation and inclusion distribution, but the technique is very weak in assessing a material's press performance. On a routine basis, average grain-size may be evaluated from the appearance of the microstructure of a sample etched to reveal grain boundaries compared with standard grain-size charts. The optimum grain-size in steel for pressing operations which involve considerable stretch-forming is usually A.S.T.M.8, (196-220 grains per sq. in.), but for deep drawing, a finer grain-size, being stronger, may resist blank-holder forces better, particularly if thin sheet is being drawn. On the other hand, coarser grained sheets have lower yield points and are desirable where buckling tends to occur over the punch face

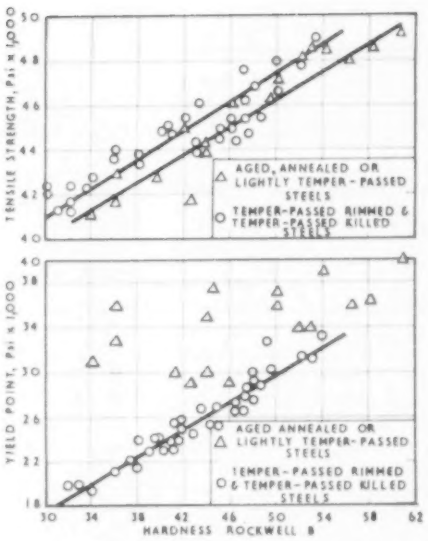


Fig. 4.—Relationship between hardness, U.T.S. and yield point for various types of steel sheet (Nelson [3])

but they may also introduce the orange-peel effect[3]. The importance of grain shape is illustrated by the superior pressing properties of aluminium-killed steels which have moderately elongated, "pancake" grains, obtained by controlling chemical composition, finish-rolling temperature, coiling temperature and annealing temperature. The processes which produce the pancake-shaped grains also develop a type of crystallographic anisotropy which favours the deformations necessary in deep-drawing. Such crystallography is examined by X-ray diffraction techniques which may indicate in the long term the sort of fundamental crystallography ideally required in a given type of pressing, but the technique is far too cumbersome for routine work. Some of the interesting results of X-ray examinations in determining the crystallography of the better deep-drawing-quality steels are introduced later in this survey.

Non-simulative Quantitative Tests

There are three main non-simulative quantitative tests which give results for predicting deep-drawing or stretch-forming quality; hardness tests, tensile tests and hydraulic bulge tests.

Although quantitative, hardness tests are almost useless in predicting the press performance of sheet[1, 2]. The tensile strengths of annealed, aged or lightly temper-rolled mild steels are proportional to hardness. The tensile strengths of fully temper-rolled mild steels are higher but still proportional to

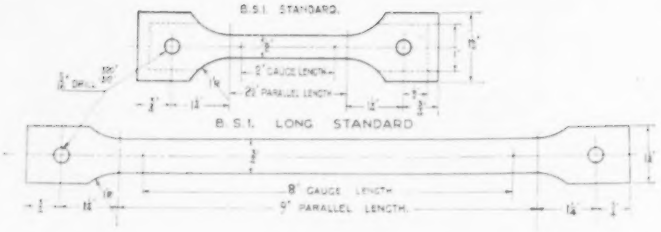


Fig. 5.—Strip tensile test-pieces suitable for use particularly with a Hounsfield Tensometer

hardness. The hardness and yield point of temper-rolled killed steel and freshly temper-rolled rimming steel can also be correlated but when a steel exhibits a yield-point elongation of 0.05 per cent or more, because of ageing or inadequate temper-rolling, there is no noticeable relationship between yield point and hardness. This is illustrated in Fig. 4 from the work of *Nelson*[3]. If hardness is related to ultimate tensile strength the uncertainty as to whether it is also related to yield point can be explained as follows. In non-ageing or freshly temper-rolled steels there is a proportional relationship between yield point and ultimate tensile strength particularly since the yield stress will probably be determined as the 0.5 per cent proof stress; thus in such steels it follows fortuitously that a relationship between hardness and yield point will appear. When a steel ages, however, the yield point will rise considerably while the ultimate tensile strength may not vary in proportion; indeed it may not increase at all. Thus, once under way, the ageing process may destroy the relationship between yield point and ultimate tensile strength and hence, with hardness. In a given steel, hardness values are useful means of following the ageing process and a useful check on the degree of temper-rolling. They can be of little use in predicting press performance and although they give a reasonable indication of U.T.S. even this value is insufficient to predict press performance of sheet. However, if instead of considering the ultimate tensile strength alone, additional results of the tensile test are considered it is frequently possible to make useful predictions of likely press performance of sheet.

It has been said recently,[4] that ". . . it is probable that the tensile test, properly interpreted, will remain the skilled metallurgist's main tool for the assessment of drawing properties and for the development and improvement of drawing properties in the many new alloys constantly assuming importance." If this is true, it should be worth examing the tensile test and its interpretation in considerable detail.

Two of the commonly used test-pieces for the tensile testing of sheet and strip are shown in Fig. 5. If sufficient test-pieces are required at any given time, sheared strips or blanks cut using sharp punch and die tools in a suitable press, are clamped between thick plates and the whole assembly is shaped or machined with a spiral milling cutter. During the final stages of machining a high-speed sharp spiral milling cutter taking light cuts with no trace of chatter is the best method of minimizing work hardening of the edges of the gauge length. For some routine tests, it is sufficient to use test-pieces blanked directly to shape. For all but rough tests it is essential that the gauge length should be accurately parallel. The practice of introducing a slight taper from both ends to the centre of the gauge length to ensure fracture within the gauge length undoubtedly introduces inaccuracies into the test results, particularly in percentage elongation results. The preparation of the test-piece should involve no bending[9]. This is most important when the test-piece is aged before testing but even when the test is carried out immediately after temper rolling it is safer to observe the same precaution. Bending will modify the residual stress system of the sheet or specimen and can produce a marked effect on the yield-point elongation particularly. The type of tensile testing machine used is usually unimportant, a particularly suitable type being the Hounsfield Tensometer with electric motor and pulley drive. Sheet tensile specimens up to a gauge length of 8 in. can be accommodated and the stress-strain curve can be recorded semi-automatically. For accurate work it is advisable to fit an auxiliary extensometer for the elastic part of the curve and to use a cathetometer to measure the plastic extension as shown in Fig. 6. For consistent results, straining speeds should be moderately low, of the order of 0.1 in. per in. per min. or less. Variations in the speed of straining a test-piece within the normal range of a test machine have limited effects on tensile results although exceptionally slow or impact straining rates do affect results considerably. Probably the most noticeable effect is on the limit of proportionality which rises with rising straining rates.

The most common form of tensile test involves the determination of the load-elongation curve with an extensometer to a strain in excess of the yield strain but less than the strain at maximum load, followed by determination of the maximum load and the total elongation, the latter being measured

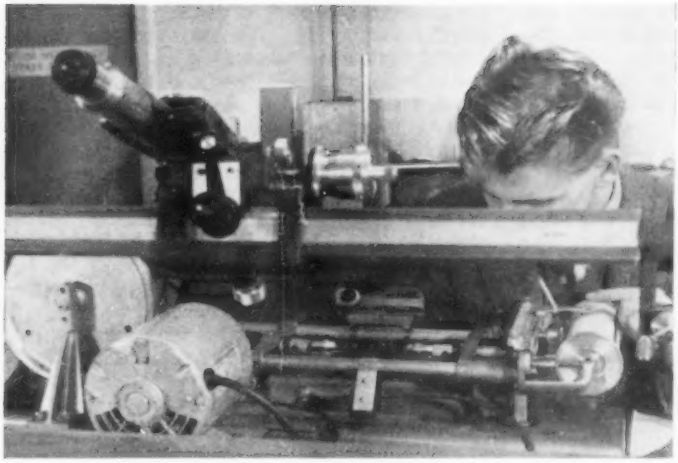


Fig. 6.—Illustration of the combined use of a cathetometer and Hounsfield tensometer for continuous observation of elongation in the plastic range

from the extended gauge length of the fractured test-piece. The following mechanical properties can then be derived from the test data. The limit of proportionality, which is the stress at which the load-extension curve departs from a straight line and the elastic limit which is the maximum stress which the specimen will bear without showing some permanent extension when the load is removed. In practice, both of these values may be regarded as the same thing and it is the limit of proportionality which is determined since this may be read from the load-extension curve whereas, theoretically, measurement of the elastic limit requires repeated loading and unloading of the specimen. The value of the limit of proportionality obtained will depend on the sensitivity of the extensometer used and for most press-work it is more useful to determine the yield point or to define the stress at which a predetermined amount of permanent extension occurs ; this being 0.1 per cent or 0.5 per cent proof stress for example. The ultimate tensile strength is calculated from the maximum load reached in the tensile test divided by the original cross-sectional area of the specimen before straining. Since necking down of the cross-section occurs in the later stages of the test the U.T.S. is not the true maximum tensile strength of the material. This localized deformation which is superimposed on the more uniform strain just before fracture takes place also affects the percentage elongation figures. The simplest measure of ductility is the total elongation which is the percentage increase in gauge length on a parallel portion of the test-piece. The total elongation will include the uniform elongation of the specimen and the localized extension due to necking down to the test-piece. Since, in press-work, localized necking down leads almost immediately to failure, it is the uniform elongation which is of interest, not the total elongation figure. There is a further complication in that a tensile specimen is pulled axially with a simple stress system whereas in presswork the stress systems will be generally biaxial. Nevertheless, it is obvious that an improvement in the usefulness of tensile test would arise from a separation of the uniform from the total elongation. This is done by dividing the gauge length into a number of equal subsections, usually eight. Taking the long standard test-piece as an example, the elongation is measured on the full eight inches of gauge length and also over a 2-in. gauge length which includes the fracture. The uniform elongation is then determined from the following relationship :

Per cent uniform elongation = (extension on 8 in.)-(extension on 2 in. G.L. including fracture) × 100/6.

Thus, the U.T.S., yield point or proof-stress, general and total elongation can be obtained from a simple load-extension tensile test, and although all of these figures are somewhat empirical since they depend on the shape of the test-piece to some extent, they may be used to predict the likely press performance of the material they represent. The degree to which this may be done is discussed later.

A load-extension tensile test curve can be plotted without a knowledge of the change in cross-section of the test-piece but if a true stress-strain curve is required the stress at every stage in the test must be expressed in terms of the true cross-section of the specimen at that stage and not in terms of the original cross-sectional area. The true stress-strain curve gives the reduction in area which a certain stress will produce, an estimate of the true maximum stress the metal will withstand, and an estimate of its work-hardening capacity from the slope of the upper part of the curve. From a practical point of view it is very difficult to measure sufficiently accurately the change in thickness of a sheet tensile specimen during the test. It is somewhat easier to measure

the change in width, although this requires considerable care, but accurate measurement of elongation is fairly simple. Since changes in both width and thickness are required to determine reduction in cross-section for the true stress, direct measurement of these values is likely to be inaccurate although still usable as an approximate guide. Fortunately, it is possible to calculate the reduction in thickness if the reduction in width and the elongation are known, at least up to the point where necking down begins. The calculation assumes that the gauge length maintains constant volume and may not be valid beyond the point where localized deformation begins to be superimposed on general deformation, since beyond this point internal fissures may occur in the gauge length thus destroying the constant volume relationship.

Arithmetically, the width strain, e_w; the thickness strain, e_t; and the length strain, e_l, are given by :—

$$e_w = \frac{w_o - w_x}{w_0}; \quad e_t = \frac{t_o - t_x}{t_0}; \quad e_l = \frac{l_x - l_o}{l_0}$$

where the subscripts w, t, and l are width, thickness and length respectively, and the subscripts, "o" and "x" refer to these values at zero strain and at strain of x per cent.

Assuming the gauge length maintains constant volume, then

$$l_o.t_o.w_o = l_x.t_x.w_x$$

If the original length, thickness and width are known accurately, the change in thickness can be calculated from the changes in length and width by substitution in the constant volume equation. At any given load then, the instantaneous cross-section may be calculated from the elongation ;

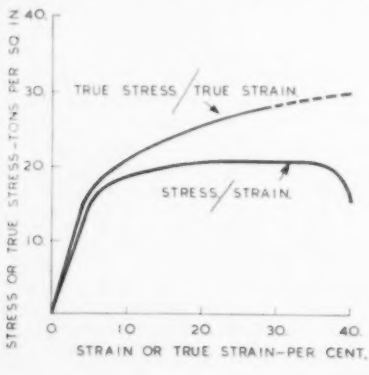
$w_x t_x = w_o t_o l_o/l_x$, and by dividing this into the load, the instantaneous true stress is obtained.

In a similar way it is necessary to measure true strain. Normally, elongation strain is measured as the percentage increase in the length of the gauge length set before the test-piece is strained. Referring elongation increments to an original gauge length is inaccurate as shown by an example in which a very large elongation is possible. If it is assumed that an 8-inch gauge length is extended to 8.8 inches this would normally be expressed as a 10 per cent elongation. Suppose the gauge length could be elongated much further to 80 inches and then a further 0.8 inches in addition. This last 0.8 inches expressed in terms of the original gauge length of 8 inches is still 10 per cent elongation but expressed in terms of the gauge length just before the final straining (80 inches), it represents a further increment of strain of 1 per cent, a much more realistic figure. The true elongation strain, e_l, may be regarded as the sum of the extensions δl produced on lengths l, which varies from l_o, the original gauge length, to l_x, the distance between the gauge marks at any stage in the test.

$$\text{Thus } e_l = \int_{l_o}^{l_x} \frac{\delta l}{l} = \log_e \frac{l_x}{l_o}$$

When the true-stress / true-strain curve is compared with the simple stress-strain curve for the same material (*see* Fig. 7) the most noticeable difference is that the true-stress / true-strain curve continues to rise beyond the point where the load-extension curve passes through a maximum because the decreased cross-section due to necking is taken into account. The true-stress / true-strain curve is a logarithmic curve of the general function $P = Ke^m$ where "P" is the true stress, "e" the true elongation strain, and "K" and "m" are constants for the material. *Norris*[5], showed that such curves plotted on a log-log basis yielded straight lines except at the extreme ends where yield-point phenomena and the difficulty of relating precise cross-sections to load near fracture introduce errors (*see* Fig. 8). The straight-line function is of the form $\log P = m \log e_l + \log K$. It can now be seen that "m" is a measure of the work-hardening ability of the material and is the gradient of the line while "K" is a starting strength index given by the intercept on the log stress axis. Both constants can be calculated either graphically or by solving two simultaneous equations after selecting two points on the line and substituting their co-ordinates in the above equation. The work-hardening index derived in this way is sufficiently accurate to be of considerable use in estimating the press performance of material as will be shown later. The ratio yield-point : U.T.S., gives a rough indication of the slope of the rising part of the load-elongation curve and so gives an approximate measure of the work-hardening effect. Another empirical demonstration of the work-hardening properties is due to *Sommer*[6] who modified conventional stress-strain curves by replacing increments of stress by stress divided by

Fig. 7.—Comparison of the simple stress/strain curve with the true-stress/true-strain curve for the same test-piece



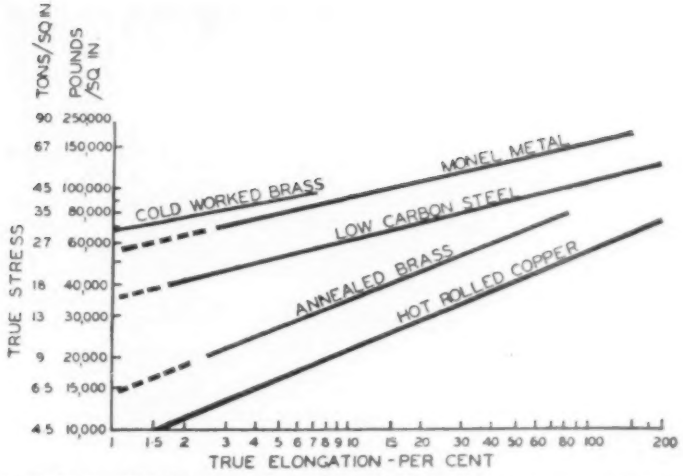


Fig. 8.—Logarithmic curves relating true stress to true strain (Norris [5])

Fig. 9.—Modified stress-strain curves devised by Sommer [5]

the U.T.S. This has the effect of showing up the relative work-hardening rates of various metals, as shown in Fig. 9. It is apparent that brass, 18/8 austenitic stainless steel and copper maintain a reasonably constant rate of work hardening throughout deformation but some metals, notably aluminium show a much lower work hardening rate as the amount of deformation increases.

In the last ten years, considerable interest has been shown in the use of the "R" value as an aid to assessing press performance of material. This value is the ratio of width strain : thickness strain in tensile testing. From the practical point of view, the determination of "R" is open to the same objections as the derivation of true stress since the change in thickness cannot be measured accurately. This can be overcome by again assuming constant volume conditions in the gauge length as follows.

In the same way that true elongation strain, $e_t = \log_e \frac{l_x}{l_o}$ then $e_t = \log_e \frac{t_o}{t_x}$ and $e_w = \log_e \frac{w_o}{w_x}$

where e_t and e_w are true thickness and width strains and the subscripts are the same as before. The anisotropy ratio "R" must then be

$$R = \frac{\log_e (w_o/w_x)}{\log_e (t_o/t_x)} \text{ but since}$$

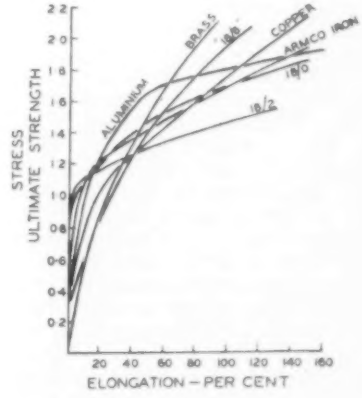
$$l_o.t_o.w_o = l_x.t_x.w_x.$$

$$t_o/t_x = \frac{l_x w_x}{l_o w_o} \text{ and so}$$

$$R = \frac{\log_e (w_o/w_x)}{\log_e (l_x\, w_x/l_o w_o)}$$

which requires no measurements of thickness strain. *Lankford, Snyder* and *Bauscher*[7], showed that "R" did not vary with increasing strain at least up to maximum load so the data necessary to determine "R" were taken at maximum load only, ten measurements being made along the 2-inch gauge length and averaged. The "R" value may vary according to the directions in which the sheet is tested. Thus, *Arbel*[8], in correcting errors in measuring the width and thickness of a tensile test-piece, nominally 0.5 × 0.125 inches, plotted a graph of thickness values against width values and assumed that proportional reduction of both dimensions would result in a straight line of slope, 0.25. In all cases a straight line was obtained but the slope was 0.25 and independent of direction of testing in the plane of the sheet, only for sheets which showed no directionality. The slopes of the lines for an alloy of aluminium/2½ per cent Mg./0.25 per cent Cr., known to be directional gave the following values :

Specimen axis; angle with rolling direction	Line slope, thickness/width during test
0 deg.	0.5
45 deg.	0.30
90 deg.	0.43



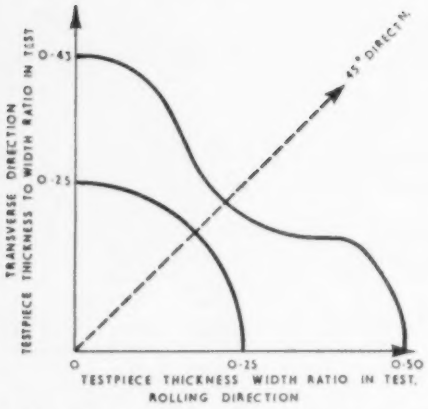


Fig. 10.—Ratio of test-piece thickness: width ratio plotted on polar co-ordinates representing direction of orientation of test-piece with respect to sheet rolling direction

By plotting these values on polar co-ordinates an indication of the degree of anisotropy is given. The more the resulting curve deviates from the ideal circle of radius 0.25, the more accentuated is the anisotropy as shown in Fig. 10.

Hydraulic Bulge Tests

When a tensile test is used to evaluate pressing quality the criterion of failure is the true stress at the point where non-uniform deformation sets in, and the strain at this point. The stresses in the test are uniaxial which is rarely the state of affairs in pressing. Biaxial stressing would be expected to reveal pressing quality better than uniaxial tests provided there are no external frictional effects. In attempting to fulfil these conditions the hydraulic bulge test can be regarded as a fundamental, non-simulative test measuring the stretching properties of the metal in the absence of friction. A suitable method of operating the test has been described by *Mellor* and *Loxley*[10]. They clamped a blank, printed with concentric gauge rings, in a holder which allowed no drawing in and exposed a 10-inch diameter disc at the centre to hydraulic bulging forces. Maximum plastic straining occurred at the pole and decreased gradually towards the peripheral clamp ring. The test is not difficult to carry out but uses a large sample. Localized deformation begins only after a much greater deformation in the hydraulic bulge test as compared with the tensile test and this allows estimations to be made on greater plastic strains and increases the sensitivity of the test. The test is frictionless and the hydraulic pressure uniform until the instant of rupture when it decreases rapidly enough to prevent overshoot. In its simplest form, the test involves the determination of the maximum hydrostatic pressure the bulged cup will withstand and its height at this point. If the thickness of the material and radius of curvature can also be measured then it is possible to calculate the tensional stress in the tangential direction at the top of the dome where

$$\sigma_t \text{ (Tangential stress)} = P\rho_o/2t$$

where P = hydrostatic pressure, ρ_o = radius of curvature of dome and t = actual specimen thickness.

During stretching, the maximum resolved shear stress will occur on planes octahedral with respect to the tangential stress and it is useful to assess the material in terms of maximum octahedral stress and shear strain.

The octahedral stress is given by :—

$$\sigma \text{ oh} = \frac{\sqrt{2}\sigma_t}{3} \text{ and shear strain by}$$

$$\sigma \text{ oh} = \sqrt{2} \log_e \frac{t_o}{t}$$

where t = final and t_o original specimen thickness. By taking progressive readings a type of stress-strain curve can be obtained.

A miniature hydraulic bulging test has been available for many years in the form of the Jovignot test, in which the sheet is hydraulically bulged into a ring die of 50 mm. bore, though other sizes are used. The bulge depth and hydraulic pressure are obtained and at failure the Jovignot cupping coefficient is taken as the average increase in surface area of the test piece within the die ring. This can be expressed in terms of the dome height at fracture, "h", and "r", the ring die internal radius.

$$\text{Cupping coefficient} = h^2/r^2.$$

If the dome is assumed to be a section of a sphere the stress-strain characteristics can be determined from pressure, dome height, die radius and sheet thickness as outlined above for the large scale test.

A similar miniature test has been described by *Gough* and *Hankins*[22], which was capable of testing thick sheet and recording the stress/strain curve automatically.

A considerable amount of work has been reported on attempts to correlate non-simulative test results with the results of simulative tests as well as with actual press results. It is therefore appropriate to outline simulative test procedures before discussing the interpretation and application of both types of test.

Simulative Tests

No simulative test yet designed can incorporate every feature of a given pressing operation. Each simulative test is therefore designed to represent one or more of the important features of a pressing operation as accurately as possible. Accordingly, simulative tests fall into a number of separate categories such as cupping tests represented by the Erichsen or Olsen tests ; cup-drawing tests such as

those developed by Swift and earlier by Erichsen ; hole-widening tests ; wedge-drawing tests and bend tests. A fairly wide range of tests is not necessarily a bad thing nor even a poor reflection of our state of knowledge on simulative testing. To quote Professor Swift[11], . . . "It was realized at the outset that in commercial practice, the forms of pressing and conditions of straining are so variable that it is unlikely that any single combination of properties can prove satisfactory for all purposes. Under these circumstances it is clearly impossible for any simple test to give a representative figure of comparative merit to cover deep-drawing operations generally. This difficulty, however, makes a clearer understanding of the underlying conditions all the more necessary." If one simple test cannot combine the necessary features it is likely that two or more tests with different characteristics will be the logical replacement.

Cupping Tests

Cupping tests, as opposed to cup-drawing tests, are based mainly on stretch-forming. Normally, the cupping is achieved by pressing a round-nosed punch into the sheet, clamped, more or less firmly according to the particular test, between the specimen holder and a ring die and the depth of penetration when fracture occurs is taken as the unit of measurement. The versions of this test due to Erichsen and to Olsen are probably used most commonly but other versions include the Avery, Amsler, Guillery, Jovignot, K.W.I., and A.E.G. tests, the essentials being described by Jevons[1].

The Erichsen test has undergone minor but nevertheless important improvements. Originally, a highly-polished ball-ended punch, 20 mm. diameter was advanced by means of a screw and handwheel against the test strip having a minimum breadth dimension of 70 mm. Before advancing the punch, the clamping ring was locked with a definite clearance between itself and the face of the die in which the specimen could move. Normally, the clearance was created by screwing the clamp ring tight against the specimen which pressed on the back of the die, and then by unscrewing the ring to leave a clearance of 0.05 mm. The blank-holder ring carried a pressure face 55 mm. external diameter and 33 mm. internal diameter. The cup was pressed forward into the die having a bore of 27 mm. and a die entry radius of 0.75 mm. The ram was advanced at about 0.1 mm. per sec. by direct screw drive for up to about 2 mm. thick or *via* a gear reduction drive for materials up to about 6 mm. thick. A graduated scale, set to zero after creating the correct clearance, recorded the advance to fracture in millimetres. It was recommended that the mid-points of impressions should be not less than 35 mm. from the sample edges and not less than 70 mm. from each other. The above dimensions relate to the standard tools but sub-standard punches and dies are available for narrower specimens.

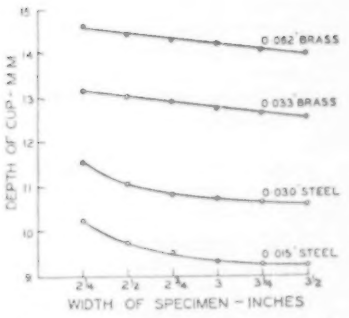


Fig. 11.—Curves relating Erichsen values to width of strip specimen for annealed 64/36 brass and low-carbon steel (Jevons[1])

In the test, the central portion of the sheet is stretched while the edge of the blank is allowed to flow in to a limited extent. The degree to which flowing in will occur is obviously dependent on the degree of friction between the die and blankholder faces and the sheet. This in turn will depend on surface conditions of tools and sheet, sheet flatness, accuracy of the clearance setting and on the degree of lubrication. These variables and the difficulty of assessing the exact endpoint of the test lead to different operators introducing different "personal" errors into this type of test. Any decrease in the width of the test specimen below the recommended standard allows increased drawing in of the flange and an apparently higher Erichsen value (Fig. 11). The Erichsen value is also influenced by the thickness of the sheet but this point is well recognized. The Erichsen value increases almost linearly with increasing thickness over the normal range of thicknesses and Erichsen values. Jevons[1], has suggested that Erichsen values should be quoted together with the sheet thickness in order to clarify this point.

Several workers have examined the reliability of the Erichsen test including variables such as specimen width, specimen thickness, specimen holder pressure, tool dimensions and surface condition, specimen flatness, lubrication, drawing speed, assessment of end point and machine rigidity, [1, 12-20]. It is not possible in this account to detail the effect of each of these variables but a few general observations are possible. It is advisable to use hard-surfaced punches, or preferably tungsten-carbide punches, if long-term freedom from variation in punch finish is required. Slight variations in punch end diameter are not significant[12] but increasing roughness of the punch decreases the cup depth[20]. This latter observation

may be explained by the fact that a rough punch tends to prevent uniform stretching of that part of the bulge in close contact with the punch nose. Increased stretching then takes place at positions remote from the pole of the bulge with consequent necking and premature fracture at such positions. A reduction of lubrication would be expected to have a similar effect. Increased sheet-holder pressure tends to prevent drawing in of the flange and decreases cup depth.

As an example of the sort of variation which may be expected between different operators and different hand operated Erichsen test machines the results of *Kokkonen* and *Nygren* in Sweden are of interest[20]. A criterion for uncertainty, in a series of measurements, as the interval within which would fall 95 per cent of the results, was used. The uncertainty of measurement made on a given material in a given machine was ± 0.4 mm. for a single impression, ± 0.2 mm. for the mean of five impressions and ± 0.1 mm. for the mean of ten impressions. Thus, the uncertainty of measurement in a given machine can be reduced to a very acceptable level by considering not less than five impressions. When considering the uncertainty of measurement using a machine arbitrarily selected from several available to the investigators, the uncertainties were ± 0.7 mm. for a single impression, and ± 0.6 mm. for the means of either five or ten impressions. In this case, the total uncertainty cannot be diminished appreciably by considering a large number of impressions from one machine since the major part of the uncertainty is due to differences between machines. Considering these results, whereas materials may be differentiated from one another with reasonable sensitivity using one machine and one operator, the sensitivity using an arbitrarily chosen machine is poor.

The remarks on the Erichsen test so far have concerned only the hand-operated machines using a positive clearance for the sheet in the blankholder. Recent developments have gone a long way to improve the accuracy of the test. Electrohydraulic test machines are now available (Fig. 12), which allow closer control over the degree to which the sheet can be drawn in from the sheet holder and automatically indicate the punch penetration to fracture. The sheet is held in the sheet-holder either with a positive clearance, which may be set more accurately than with the hand machines, or with a specified hydraulically loaded sheet-holder pressure. The movement of the punch, by hydraulic means, is smooth and easily regulated and the end-point is indicated by the automatic stopping of the machine at the point when the resistance to the punch just begins to decrease at fracture.

Further improvements have been achieved in certain European countries by revising the specification of the test conditions. Briefly the Euronorm version of the test[21] differs in no way on tool dimensions, although tolerances are quoted, but the minimum specimen width is given as 90 mm., the specimen is subjected to a sheetholder pressure of 1,000 kg. instead of positive clearance, and the type and degree of lubrication (by graphitized grease) is specified. The closeness of the centre of impressions to the edge must not be less than 45 mm., and to each other, 90 mm. In the present author's opinion there is no doubt that this new specification increases the reproducibility of the Erichsen test.

Fig. 12.—One of a series of electro-hydraulic machines, for carrying out a variety of stretch-forming and deep drawing tests, made by A. M. Erichsen, G.m.b.h.

The appearance of the outer surface of the dome produced in the Erichsen test is a useful indication of certain sheet properties. The degree of roughness of the dome is closely related to the average grain-size of the metal and grain-size may be estimated by comparing a specimen surface with a series of standards at low magnification. The mode of fracture is also of interest in that an almost continuous circle around the wall of the dome is an indication that the sheet does not possess markedly directional properties. On the other hand, straight-line fractures are indicative of directionality.

Other cupping tests work on similar principles to the Erichsen tests. The Avery test uses the same

(Continued in page 674)

QUALITY CONTROL

in the Production of Steel Sheet for Deep Drawing and Pressing*

By W. O. THOMAS, A.I.M.†

Introduction

THE rapid growth of the motor-car industry during the past 30 years has led to an increasing demand for cold-reduced sheets. This demand has been met by the rapid development of new strip-mill capacity. Another important feature in the growth of the industry is the evolution in the shape of motor cars from the simple shapes of 30 years ago to the streamlined intricate shapes of today. Presses of greater power and speed producing deeper and more intricate pressings demand a steel sheet of improved ductility and surface quality.

To maintain and improve a high standard of quality an exacting quality control system is essential throughout all stages of processing from raw materials to finished sheet.

The main criteria of quality of cold-reduced sheet are ductility and surface finish. The trade terms employed for both these are defined in Table I.

The sheet-user decides which surface quality is required for a particular part and the supplier normally decides the standard of ductility required.

Most strip mills employ a quality adviser who decides steel grade and the processing treatment which must be employed for new orders. The decision is based mainly on examination of the pressed component or photographs and drawings of the part. Sometimes a scribed blank is pressed and the maximum increase in area is measured. The increase in area gives an indication of the ductility necessary to give a satisfactory performance on that particular job.

The quality adviser stipulates the steel grade, hot-mill finishing and coiling temperatures, percentage cold reduction, annealing cycle and percentage temper rolling for all orders. In practice, however, finishing and coiling temperatures are standardized for all EDD material, the percentage cold reduction is determined by the ordered gauge and hot-mill limitations, while the percentage of temper rolling is determined by the surface quality required by the customer. Thus the main controls left to the quality adviser are steel grade and annealing cycle.

In the United Kingdom and U.S.A. deep-drawing steels are rarely supplied to a specification but to do a particular job. If the scrap panels and panels requiring repair due to ductility or surface defects

* One of a series of lectures presented in the course on "The Technology of Deep Drawing and Pressing," Birmingham College of Technology.

† The Steel Co. of Wales Ltd.

TABLE I—*Definition of Trade Terms*

	Quality	Description
Ductility	Extra Deep Drawing (E.D.D.)	Suitable for exceptionally severe draws and/or pressings
	Deep Drawing (D.D.)	Suitable for severe draws and/or pressings
Surface Finish	Full Finish (F.F.)	High standard of surface finish, suitable for visible parts
	Enamelling (En)	Surface specially prepared for vitreous enamelling
	General Purpose (GP)	Reasonably free of surface defects, should not be used where a high standard of surface finish is desirable

TABLE II.—*Typical Composition of Steel Company of Wales Ltd., Blast Furnace Hot Metal*

Process	Carbon	Sulphur	Silicon	Phosphorus	Manganese
Basic Open Hearth	4.00	0.020	0.5	0.41	0.6 to 0.9
V.L.N.	4.00	0.022	0.4	2.04	0.7

exceed an agreed percentage then a claim may be made against the steel producer.

If a part gives trouble under the press which can be attributed to lack of ductility the routing is reviewed and future orders may be applied from a superior steel grade and/or be given a longer annealing soak time.

Where persistent trouble is experienced the use of stabilized EDD steel may be recommended.

Material Control

The first essential in producing EDD steel is correct analysis. To achieve the desired specifications in the steel plant, close control of hot metal and scrap chemical composition is imperative. A typical analysis of hot metal for the basic open hearth and V.L.N. processes is shown in Table II. (V.L.N. = Very Low Nitrogen steel produced by oxygen/steam blowing for the whole of the blow in the bottom-blown basic pneumatic process).

The hot metal from the blast furnaces is stored in a mixer which, besides acting as a reservoir, will even out variations in analysis of the blast-furnace metal fed to the open-hearth furnaces or converters.

Steel Scrap

A low level of nickel, copper and tin is essential in steel of EDD quality and as the removal of these elements is not possible in the steel-making processes the amount introduced must be rigidly controlled. Steel scrap, (ingot ends, scrap slabs) from E.D.D. material is segregated during processing and fed back to E.D.D. charges. Scrap which is foreign to the works (bought scrap, engineering scrap) is analyzed to ensure that material which is high in "tramp" elements is not introduced to charges intended for E.D.D. sheet.

The pneumatic processes, being relatively small consumers of scrap compared with the open-hearth processes, generally have an advantage in the level of "tramp elements".

Steel Making

Typical pit analyses for steel ingots destined for E.D.D. sheets are shown in Table III.

Rapid and accurate chemical analysis is achieved by the use of modern direct-reading methods of analysis such as the quantometer and quantovac. Equipment for rapid transportation and preparation of samples is employed.

The major open-hearth plant problem is to achieve a low carbon, phosphorus and sulphur content in the minimum time. With the use of oxygen during refining the removal of carbon and sulphur to low levels is simplified. Oxygen blowing commences when the carbon level is between 0.3 and 0.4 per cent and continues until the specification is reached.

The control of sulphur content in the blast-furnace metal and the steel scrap, ensures that the minimum practical amount has been introduced into the charge, but unfortunately sulphur pick-up from the furnace atmosphere occurs, especially during the melting of the charge. This sulphur pick-up is generally minimized by control of the sulphur content of the fuel oil. The sulphur and silica content of the limestone and lime additions to the furnace are also controlled.

Carbon pick-up occurs from the ferro-manganese additions, thus regular checks on the carbon content of the ferro-manganese are carried out. For some special grades a low-carbon ferro-manganese is used, this, however, is not economic for general use.

The temperature of the molten metal in the furnace bath is important for a number of reasons.

1. High temperatures may cause excessive erosion of the furnace hearth, reducing production and increasing the amounts of non-metallic inclusions present in the steel melt.
2. The low carbon content required results in a steel of a high state of oxidation. Increased bath temperatures further increase the state of oxidation to an undesirably high level.

TABLE III.—*Typical analyses of E.D.D. Rimmed steel*

Quality	C.	S.	P.	Mn.	Ni.	Cu.	Sn.	N_2
O.H. E.D.D. Rimmed ..	0.065	0.026	0.013	0.34	0.060	0.070	0.01	0.0035
V.L.N.* E.D.D. Rimmed..	0.055	0.024	0.023	0.29	0.050	0.040	0.01	0.0011

* V.L.N. = very low Nitrogen.

3. Too low a tapping temperature can result in poor teeming conditions giving a poor ingot surface and also "skulling" *i.e.* solidification of some metal in the ladle.

From experience the optimum tapping temperature at Abbey Works was found to be 1,570 to 1,590° C. This is now standard practice and the metal temperature is frequently measured by quality control staff using platinum / platinum-rhodium immersion thermocouples.

Deoxidation

Two main grades of steel are used for E.D.D. material, these are rimmed and stabilized; the compositions are very similar except that stabilized steel is completely deoxidized (killed) by the addition of aluminium either to the ladle or the mould. Rimmed steel is only deoxidized to the extent necessary to obtain a level rimmer in the mould. The ferro-manganese addition brings the manganese level to specification but manganese is too weak a deoxidizer for this addition to suffice as a control on highly-oxidized rimming steel. The addition of manganese is made primarily to alleviate hot shortness and further deoxidation is normally necessary. This is carried out by aluminium additions to the ladle and the mould. It is the object of most rimming-steel manufacturers to deoxidize mainly in the ladle, so that only relatively small corrective additions are required in the mould.

The assessment of the state of oxidation of the molten steel in the furnace is very difficult. Various control methods are employed such as relating the aluminium additions to the ladle to the rate of carbon drop, carbon content at tap, residual manganese at tap, iron content of the slag and temperature at tap. The method or combination of methods used is generally determined by practical experience at each melting shop. The method used at the Steel Company of Wales Ltd. is based on the carbon at tap, rate of carbon drop and iron content of the slag.

Rimmed Steel

There are four main reasons why rimmed steel is so widely used for deep-drawing purposes:—

1. A better surface can be obtained because of removal of non-metallic inclusions from near the surface by the flushing action of the gases produced by the rimming action (carbon-monoxide is formed by the action of dissolved oxygen or FeO on the residual carbon in the melt).
2. The rimming action $FeO + C = CO + Fe$ removes as much as 0.015 per cent of the residual carbon in the melt. Thus the sheet carbon content of rimmed steel is generally considerably lower than that of the ladle metal.
3. A higher ingot/slab yield is obtainable because of the absence of the deep-seated pipe cavity which is present in killed steel.
4. Complete deoxidation with silicon or aluminium would increase the tensile strength and hardness.

A disadvantage is that chemical segregation is greater than in a killed steel. The top of the ingot is the most heavily segregated portion, thus the top 35 per cent of rimmed steel ingots is not used for difficult E.D.D. jobs, but is applied to flat work orders. This greater amount of segregation is the penalty paid for the relatively pure rim. During solidification pure iron tends to solidify first, enriching the adjacent liquid in carbon, sulphur and phosphorous. The flow of gas bubbles up the solid/liquid interface causes a circulation of metal up the advancing solid wall. This circulation removes the enriched liquid from the immediate vicinity of the solid/liquid interface and relatively pure iron continues to solidify, the remaining liquid metal is continuously enriched by carbon, sulphur and phosphorous.

It is the continuous removal of the enriched liquid from the solidifying face by circulation created by gas evolution which is responsible for the pure rim and impure core characteristic of rimmed steels.

The variation in chemical composition brought about by segregation gives some variation in the mechanical properties obtained in sheets from different heights in the ingot. There will also be some variation from edge to centre of sheets.

The amount of segregation is controlled by the time the ingot is allowed to rim and the vigour of the rimming action. Short rimming times give less segregation but lower carbon loss. The practice at the Steel Company of Wales Ltd. is to allow the ingots to rim for 20 to 23 minutes before the rimming action is suppressed by plating. Plating chills and solidifies the surface so the gas bubbles cannot escape, the subsequent pressure build-up inhibits the reaction between FeO and carbon.

The production of large numbers of "top cuts" which are difficult to apply to orders, and being short, a considerable hindrance to strip-mill production, is an acute embarrassment to most manufacturers of E.D.D. sheet. Many American firms have overcome the problem by using thinner ingots (22 in.). The level of maximum segregation in these ingots is higher than in ingots of conventional cross-section and consequently the whole ingot can be applied to E.D.D. orders.

Another way of overcoming this major difficulty is the use of bottle-top ingots in which the metal is made to rise by adding sufficient aluminium at finished teem. The ingot top is constricted and a round cap is inserted in the top opening after finish teem; the rimming action is suppressed when

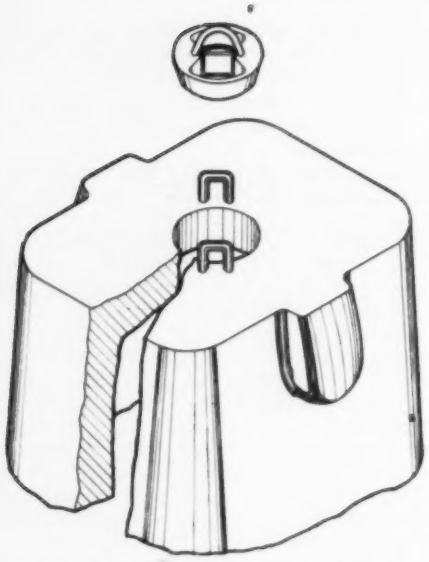


Fig. 1.—Bottle top mould with cap

the metal rises to the cap. A diagram illustrating the top portion of a bottle-top mould is shown in Fig. 1. Fig. 2 shows a typical bottle-top ingot. The time between finish teeming and cessation of rimming is generally between 2 and 5 minutes, this time is sufficient to give a satisfactory rim thickness with minimum segregation. The mechanical properties of sheets from bottle-top ingots vary less across the width and from top to bottom of the ingot than do sheets from open top rimmed ingots, this is a distinct advantage to the consumer. The shorter rimming time gives a lower carbon loss, thus a lower tap carbon level is necessary for bottle-top steel than for the equivalent open top quality. Because of differences in ingot structure the ingot/slab yield of bottle-top steel is higher than that of open-top steel.

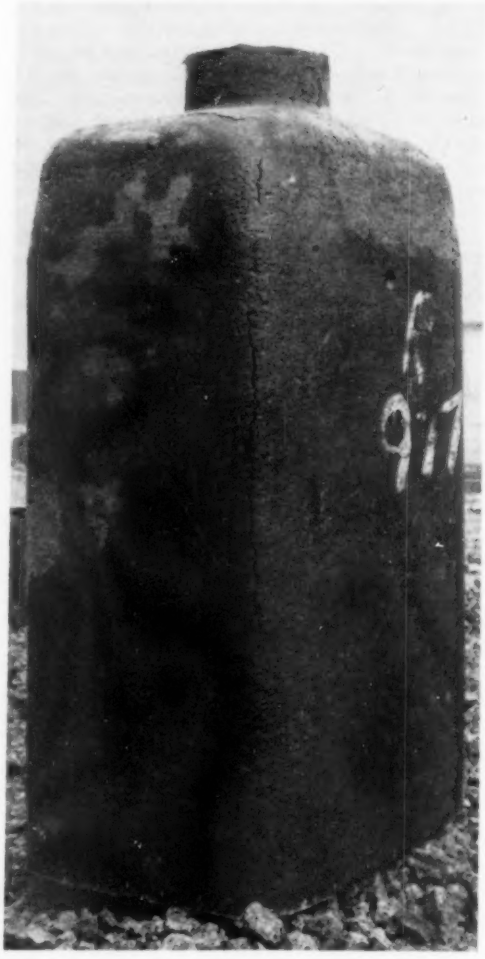
The type and amounts of non-metallic inclusions present in rimmed steel have an important influence on the mechanical properties of the finished product. The amount of exoginous inclusions is influenced by steelmaking, ladling and teeming practices, as well as by choice of refractory materials. The state of oxidation in the bath, and the deoxidation practices employed, both influence the type and amount of indigenous inclusions in the steel.

SURFACE QUALITY OF RIMMED STEEL

The deoxidation and teeming practices have extremely important effects on the ingot, and subsequently, the sheet surface condition.

It has already been remarked that one of the important advantages of rimmed steel is that the rim is relatively free of non-metallic inclusions, thus a better surface is obtained. The surface condition of slabs from rimmed ingots depends, to a large extent, on the distance of the blowholes from the ingot surfaces. Blowhole depth depends on the vigour of the rimming action, which, in turn, is controlled by the state of oxidation of the metal when tapped and by the deoxidation techniques employed. Fig. 3 shows the effect of state of oxidation on depth of blowholes. The surface blowholes in the over-oxidized ingot are attributed to a rapid gas evolution, not just at the cold surface of the mould, but throughout the mass of liquid. The mould is filled with froth, some bubbles of which are trapped on the surface to give the type

Fig. 2.—Bottle top ingot. (Corner cracking is unusual)



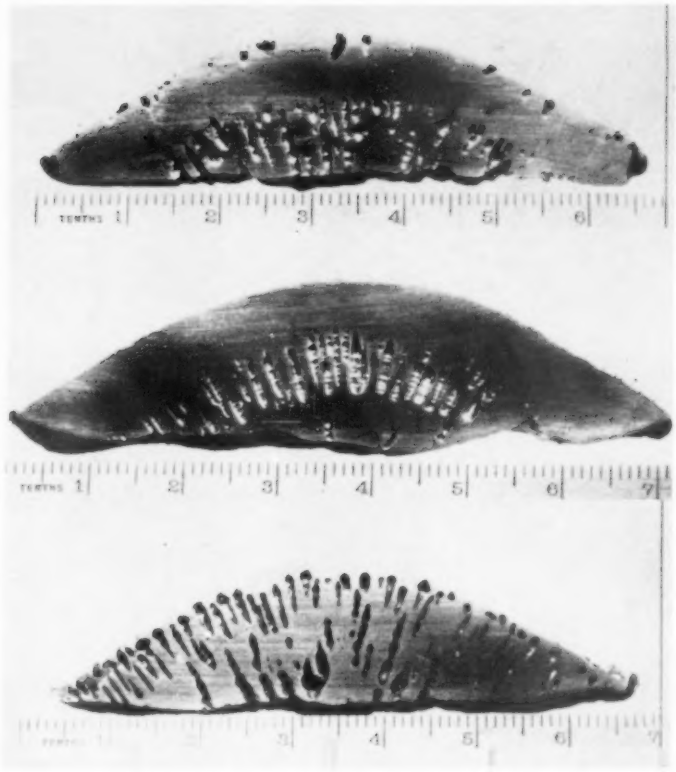


Fig. 3.—Influence of state of oxidation on surface blowholes of rimmed steel ingots.

(a) Corner sample from over-oxidized ingot

(b) Corner sample from an ingot which rimmed correctly during filling

(c) Corner sample from an under-oxidized rimmed ingot

of blowholes shown in the corner sample at the top of Fig. 3([2]).

In addition an over-oxidized steel is undesirable because of:—

1. Excessive segregation.
2. Lower slab yield.
3. Surging during filling.

Surging causes the metal level to rise and fall leaving a chilled shell on the mould wall termed a "lap". This lap gives a serious slab defect. In a highly-oxidized steel the vigorous gas evolution tends to give a frothy liquid metal condition and a sudden escape of the gas allows the liquid to drop in level. This may occur on numerous occasions during the filling of the ingot as well as at top teeming level.

Under-oxidized steel (corner sample at bottom of Fig. 3) is undesirable because of the proximity of the blowholes to the ingot surface. With this degree of oxidation the gas evolution is not so vigorous and the ferrostatic pressure of the metal in the mould may be sufficient to entrap the gas bubbles. The metal level rises after teeming is completed, hence the term "rising rimmer". This type of ingot, as well as the highly over-oxidized ingot, has blowholes close to the surface and consequently may give rise to severe slab surface defects which have various names *e.g.* "reeds", "spongy surface", or "dryness". The defect is seen as numerous fine cracks over the slab surface, one form of the defect is shown in Fig. 4.

At the optimum oxidation level (corner sample in middle of Fig. 3) the gas evolution at the surface keeps pace with the gas bubble formation in the solidifying steel. Steelmaking, and ladle and mould deoxidation practices, are aimed at giving this type of ingot. Aluminium additions to the ladle have already been described; final control of the state of oxidation is carried out by the addition of relatively small amounts of aluminium to the mould.

Finely-powdered iron ore, scale, sodium fluoride, or commercial "rimming agents" are sometimes added to improve the rimming action of under-oxidized ingots where gas evolution is sluggish.

Splash

Splash is another serious difficulty which affects both rimmed and stabilized steel ingots. This gives rise to "shell" on slabs and if not removed results in the sheet surface defects termed

Fig. 4.—"Dryness" on hot-rolled slab before scarfing

"slivers". Fig. 5 shows "shell" on a slab and Fig. 6 illustrates the resulting sheet defect termed a "sliver".

The metal stream from the ladle hits the cast-iron bottom pad on which the mould rests with considerable force and molten metal may splash and solidify on the mould wall. A sudden change in teeming rate from slow to fast may cause the metal to surge up the mould wall leaving a solidified shell. Poor teeming streams, such as splaying streams, which may strike the mould walls are another cause of splash defects.

Most steel-makers arrive at their individual solutions to the splash problem. Splash cans are frequently used to prevent the splashed metal from reaching the mould walls. Mould dressings of various kinds are sometimes used, in theory—the coating prevents the splashed and solidified metal from adhering to the mould wall, the piece then falls into the molten pool and melts. The problem of splash can be overcome almost completely by employing bottom pouring instead of top-pouring. This method, however, is rarely used for D.D. steels because of (1) the increased non-metallic inclusions picked up from the refractory trumpet and runners and (2) higher production costs.

When top pouring the force of the molten steel striking the cast iron bottom plate gives excessive wear and hence high bottom plate consumption. This can be overcome by laying refractory brick inserts in the bottom plate, and protecting these by mild-steel pad plates. When eroded the bricks can be replaced.

Stabilized Steel

Aluminium-killed E.D.D. steel is used mainly because of its non-ageing properties, the aluminium may be added either in the ladle or the mould. When mould stabilization is employed, the product is called rimmed-stabilized steel.

From the ductility angle, apart from its non-ageing characteristics, stabilized steel has two advantages over rimmed steel. It is slightly cleaner

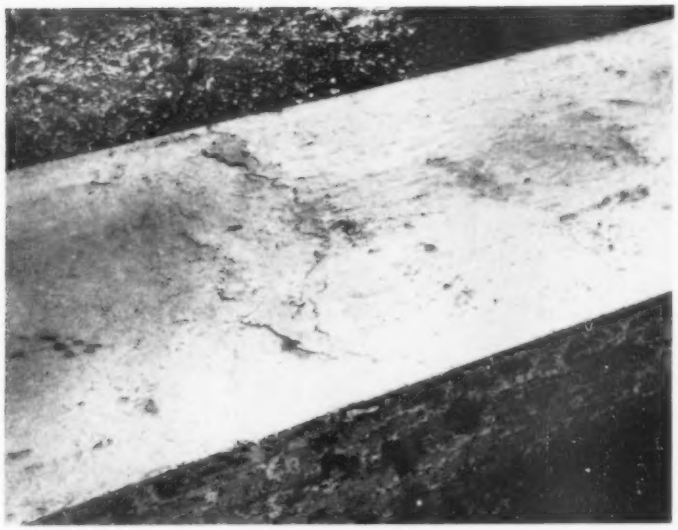


Fig. 5 (left).—"Shell" on slab

Fig. 6 (below).—"Sliver" on sheet, the result of "shell" on the slab

and segregation is less, thus whole ingot application can be employed. The disadvantages are: (1) there is no carbon loss in the mould from ladle stabilized steel and only a slight loss in rimmed stabilized steel; (2) the aluminium content must be rigidly controlled, generally 0.03 to 0.04 per cent is ideal. Below 0.02 per cent the steel may show ageing, and with increasing aluminium contents the sheet is fully stabilized but the hardness increases. The distribution of aluminium is good in ladle-stabilized steel, but may give occasional difficulties in the rimmed - stabilized variety. Various methods are used by different plants to ensure proper distribution of aluminium in rimmed-stabilized steel.

Surface Quality of Stabilized Steel

Relatively large amounts of alumina are formed during complete deoxidation and some of this alumina is washed towards the mould wall giving aluminium stringers at the ingot surface. Thus ladle-killed steel requires heavy surface dressing in the slab yard. This difficulty is largely overcome in rimmed-stabilized steel because the ingot is virtually a rimming-steel ingot during filling. The aluminium additions (which amount to 3 lb. per ton at Abbey) are made between 12 and 18 in. from top teeming level and the force of the stream is sufficient to distribute the aluminium throughout the ingot. The rimming action during filling gives a pure rim, thick enough to overcome the problem of aluminium stringers.

Rimmed-stabilized steel overcomes some of the surface problems, but it still has the disadvantage of a low ingot/slab yield compared to rimmed steels.

The loss of product due to poor surface and low slab yields has stimulated much research to improve the quality of aluminium-killed steels and to develop new steels which might replace it. It was found that small additions of vanadium or boron added to rimmed steels resulted in sheet steel which was non-ageing, even though it rimmed satisfactorily.

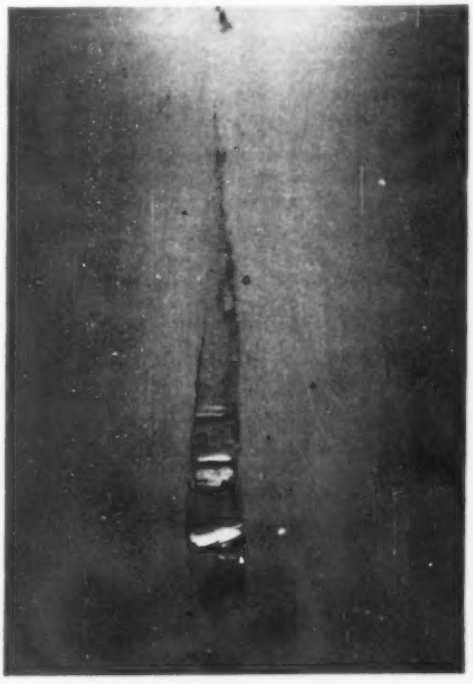


Fig. 7.—Finishing train of a hot-strip mill

Thus it was possible to produce a non-ageing sheet steel which had the good surface quality of rimmed steel, rather than the poor surface of ladle-killed aluminium steel. The slab yields are also higher.

The commercial use of vanadium and boron rimmed non-ageing steels is not yet widespread. This is due to (1) difficulty in obtaining a sufficiently high boron or vanadium content without excessive loss, and (2) difficulty in maintaining the rigid control necessary in both the hot mill and annealing plants in order to obtain the low level of uncombined nitrogen necessary to avoid strain-ageing.

Hot Rolling

A minimum standing time (*i.e.* time from finish teeming to moving the train) is necessary, depending on the ingot size. This is in order to avoid any danger of blowing or bleeding during transit. The ingots are stripped at least 1½ hr. after "finish teem" and charged to soaking pits for heating prior to slab rolling. The soaking temperature for rimming steels is about 2,350° F. (1,288° C), the furnace atmosphere should be slightly oxidizing so that the scale formed is easily removed during rolling. If the soaking period is prolonged or the atmosphere too oxidizing, sufficient surface metal may be removed by scaling to expose. subcutaneous blowholes resulting in seamy slabs. Some loss of surface by scaling is beneficial because shell can be partly or wholly removed.

At Abbey Works, the ingots are rolled to slabs in a universal mill which has one horizontal, and one vertical pair of rolls. The ingot sizes are usually designed to give two slabs 18 ft. × 5½ in. to 8 in. thick. The finishing temperature at the slabbing mill should be about 2,000° F. (1,093° C.). Some mills can roll directly to coil by passing the slabs direct to the strip mill. This, however, requires co-ordination of the slabbing and strip mill schedules, which is difficult to achieve.

Many strip mills are provided with machine scarfers so that the surfaces, edges or both can be removed. Machine scarfing of all surfaces is normally practised on all slabs for F.F. orders.

The slabs are identified by mechanical stamping, transferred to the slab yard and allowed to go cold. They are then scarfed by hand if necessary. The efficiency of these scarfing operations determines to a large extent the final surface quality of the sheet with respect to steel defects.

The slabs are reheated in slab reheating furnaces prior to rolling to strip in the strip mill. The furnace soak zone temperature is generally 2,300 to 2,400° F. (1,260 to 1,316° C.).

The slabs pass through a scale breaker, 4 roughing mills, (the slab is in only one roughing mill at a time) and onto the delay table. The partly rolled slab passes through the secondary scale breaker and through the 6 finishing mills onto the run-out table and thence to the coilers. Water sprays are used between each finishing stand to keep the surface free from scale. The run-out table at S.C.O.W. is 103 yards long and is equipped with specially designed water jets to cool the strips to

the required coiling temperature. Fig. 7 shows a general view of the finishing stands and delay table of a hot-strip mill.

Hot-strip mill practice has an extremely important effect both on the surface quality and ductility of the finished product. The hot-rolled grain size and carbide size are controlled mainly by the finishing and coiling temperatures in the strip mill. The finishing temperature is measured by a radiation pyrometer situated immediately before the last stand of the strip mill, the surface temperature at the middle of the width is recorded. The coiling temperature is recorded by a similar instrument placed at the end of the run-out table and just in front of the coilers.

The effect of mill temperatures on the hot band structure is shown schematically in Fig. 8[1]. The optimum structure of uniform equiaxed grain-size with finely dispersed carbide particles is obtained by finishing above the upper critical temperature (Ar_3) and coiling below the lower critical (Ar_1).

The specified finishing and coiling temperatures at Abbey Works for both E.D.D. rimmed and stabilized coils are 1,600 to 1,670° F. (871° C to 910° C) and less than 1,200° F. (650° C.) respectively. Coils with temperatures outside these limits are rejected.

Hot-mill treatment has an important effect on the final grain shape of Al.-killed stabilized steel. In order to obtain the desired pancake grain-structure after annealing, full solution of the aluminium nitride and retention of this compound in solution is essential[3]. This is achieved by quenching rapidly and coiling below 1,200° F. (650° C.).

When the finishing and coiling temperatures are both high a uniform coarse-grained structure with massive carbide particles results. This structure is due to normal grain growth and would give, after cold reduction and annealing, a product with a fairly coarse grain-size and carbides in stringer form. Though the steel would be soft, there might be a tendency to give an "orange-peel" effect on pressing due to the coarse grain. The stringer carbides would reduce the ductility in the transverse direction.

When the finishing temperature is low (below the Ar_3) and the coiling temperature low, the grain-size will be mixed—coarse at the surface. An extremely coarse surface grain-size would be obtained by coiling hot.

Finishing at a still lower temperature, (near the Ar_1) results in elongated ferrite grains; with a low coiling temperature this structure is retained, but a high coiling temperature results in an extremely coarse grain-size.

The coarse grain-size which results from finishing cold (below the Ar_3) is the result of recrystallization from a small number of nuclei after a small amount of cold working.

The phenomenon of abnormal grain growth by annealing following small amounts of cold work was investigated by Edwards and Pfeil[4] who by controlled small amounts of cold work followed by low-temperature annealing produced large single crystals of low-carbon steel.

The finishing temperature is affected by:—

1. The slab reheating furnace temperature.
2. By holding the slab on the delay table prior to entering the finishing stands.

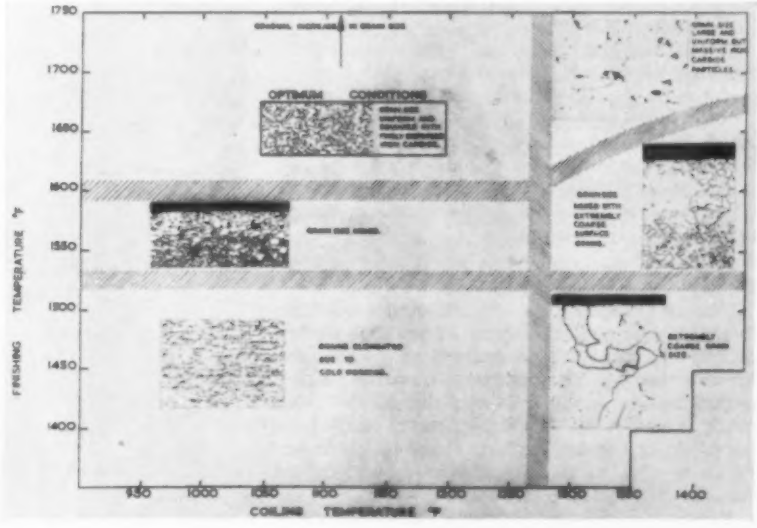


Fig. 8.—Effect of hot-strip-mill finishing and coiling temperatures on the micro-structure of hot-rolled strip

3. The strip speed.

Holding slabs at the delay table or running at a slow speed would lower the production rate so the finishing temperature, in practice, is controlled by the furnace temperature.

The coiling temperature is affected by the above factors, also by the finishing temperature and the water sprays on the run-out table. In practice control is exercised by varying the number of spray banks in operation.

An important point in the control of strip mill operation is the relationships which exist between mill speed, gauge, finishing and coiling temperatures. Higher mill speeds and/or heavier gauges give a higher finishing/coiling temperature for a given slab temperature and run-out table water spray practice.

It should be noted that the temperature of the strip during rolling varies through the cross-section, the surfaces and edges obviously being colder than the interior, the hot-mill structure is affected by these temperature differences.

The effects of an unsatisfactory hot-rolled structure cannot be eradicated by subsequent cold reduction and annealing, thus it is extremely important that the hot-rolling temperatures are rigidly controlled.

Surface Quality

The major defects originating in the hot-mill which affect the final product if proper control is not exercised are:—

1. *Scale defects—Rolled-in-scale and fleck scale.*—High-pressure water sprays (up to 2,300 lb./sq. in.) are used to remove primary and secondary scale. Low water pressure, blocked spray nozzles, improper reheating furnace atmosphere control can all lead to trouble.

2. *Pits and Scrap Marks.*—These are caused by small pieces of steel, detached from the edges or surfaces, being rolled into the surface.

3. *Scratches and Roll Marks.*—Also give defects which affect the finished product. Regular thorough examinations of the hot-rolled strip and immediate corrective action in the case of trouble can be effective in minimising surface defects originating in the hot-mill.

Pickling

The next process is the removal of the scale layer in the continuous pickle lines. The major surface defects which can be introduced at the pickle lines, are overpickling, underpickling, scratches, digs—caused by soft pinch rolls and coil break. Coil break is the result of discontinuous yielding on uncoiling, and during bending in the scale-breaker. Fig. 9 illustrates a typical example of coil break on cold-reduced and annealed sheet.

Careful observations of the surface condition at this stage and prompt action to correct defects is important. The acid content is regularly checked and the temperature continuously recorded.

Cold Reduction

Cold reduction to the gauges required for E.D.D. material is normally performed on a 3- or 4-stand tandem mill.

The amount of cold reduction given is an important factor in the grain-size of the finished sheet. Larger amounts of cold reduction reduce the recrystallization temperature and gives a smaller grain-size. The ideal amount of cold reduction is 40 to 45 per cent, less than this would give a coarse grain-size with the undesirable "orange peel" appearance on pressing. Above 45 per cent increasing amounts give rise to a smaller grain-size. In practice the limitations of the hot-rolled coil dimensions frequently necessitate heavier degrees of cold reduction than this ideal, *e.g.* with an ordered sheet size of 60 in. × 0.036 in. the hot band gauge at Abbey is 0.088 in., giving just under 60 per cent cold reduction. It is extremely difficult for a hot-strip mill to roll 60-in. wide sheet to a thinner gauge than 0.088 in.

Another effect of cold reduction is that fragmentation of coarse and stringer carbide particles can occur particularly when the reduction is heavy.

Fig. 9.—Coil breaks

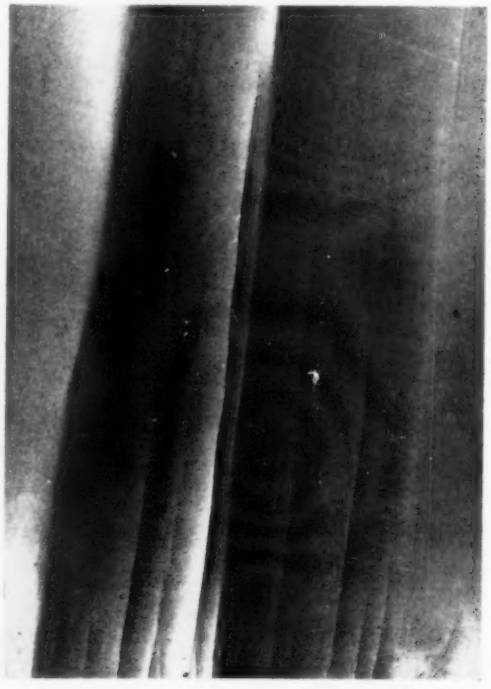


Fig. 10.—Wrench marks

Stabilized steel because of its aluminium content tends to have a finer grain than E.D.D. rimmed steel given similar processing conditions. The smaller grain-size would increase the hardness and in order to avoid this the percentage cold reduction on stabilized steel is 50 per cent maximum wherever possible.

The cold-mill treatment, besides being important from the ductility angle, plays an important part in the final surface quality. Surface defects can be caused directly or indirectly. Some defects arising directly from cold-mill processing are roll marks, water stains and pits and scrap marks.

Wrench marks are defects arising indirectly from cold reduction. These are the result of pressure welding during annealing which causes laps of the coil to stick to one another. This sticking of wraps together causes irregular unwinding of the annealed coil on skin passing which is sufficient to give the defect shown in Fig. 10. This defect is very similar to coil break in that it is the result of discontinuous yielding. Skin passing is not always heavy enough to remove the marks. Rigorous precautions are normally taken to minimise the incidence of these defects. The annealing temperatures cannot be reduced because they are essential in order to achieve the required high standard of ductility. Control is, therefore, exercised on the pressure between the wraps of the coil by regulating the coiling tension at the tandem mill and by control of cold reduced shape. The surface roughness of the cold-rolled strip affects the level of wrench mark rejections. This could be attributed to one or both of the following mechanisms:—

(*a*) A rough surface reduces the surface area in contact and thus requires less stress to part the two sticking surfaces.

(*b*) A rough surface holds a larger amount of the cold reduction lubricant residues, the less clean surface may inhibit pressure welding.

A minimum surface roughness of 60 micro-inches is considered desirable at Abbey Works; other mills may have different levels to suit their own practice.

This rough surface finish is obtained by using shotblasted rolls in the final stand of the tandem mills. The shot-blasting practice is rigidly controlled and the surface roughness of the finishing rolls and the coils is measured. Care must be taken that the shotblasted pattern imprinted on the sheet is not coarse otherwise surface coarsening on pressing may arise.

Annealing

The cold-reduced material has to be heat treated to restore its ductility (lost during previous cold work) by controlled recrystallization of the deformed grain structure. The heat-treatment process applied to cold-reduced sheet steel consists of heating to a temperature below the lower critical temperature (Ac_1 approx. 1,330° F. (721° C.), holding at this temperature for a specified time and furnace cooling. This type of annealing is termed "process" or "sub-critical" annealing.

Commercial annealing experiments at the Republic Steel Corporation, U.S.A.[5] have shown that only partial relief of the cold-working stress was achieved by a soaking temperature of 1,150° F. (621° C.) for three hours; and full stress relief was obtained by a temperature of 1,180° F. for 12 hr. (638° C.). Higher temperatures and longer soak times increase the grain-size as well as bringing about coalescence of the carbides. As previously mentioned the final grain-size and carbide structure of the annealed product depends on the structure of the hot-rolled band and the percentage cold reduction as well as the time and temperature of annealing. The rate of heating also has an important effect on the final grain-size but in box annealing rapid heating rates cannot be achieved so this factor is not of practical significance.

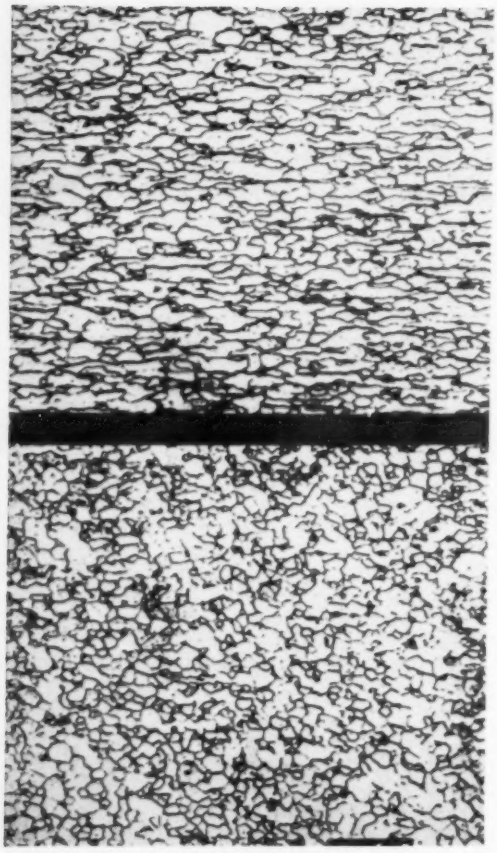


Fig. 11.—Micro-structure of annealed EDD sheet (top)—Stabilized steel. (Pancake grain structure). (bottom)—Rimmed steel. (Equiaxed grain structure).

The ideal structure of E.D.D. rimmed steel is an equiaxed ferrite grain-size of A.S.T.M. size 6 with randomly distributed small spheroidal carbide particles. In practice, because the percentage cold reduction is usually 50 per cent. or above, the grain size is normally A.S.T.M. 7. Typical micro-structures of rimmed and stabilized cold-reduced and annealed sheet are shown in Fig. 11.

Stabilized steel normally has a pancake grain-size due to the presence of aluminium nitride particles. The pancake appearance of the grains is due to elongation of the annealed ferritic structure in the direction of rolling. This is attributed to an inhibiting effect of aluminium nitride precipitation on the recrystallization of the grains during annealing. The preferential precipitation of aluminium nitride (which has been held in solution during hot-rolling) before reaching the recrystallization temperature mechanically obstructs the development of an equiaxed structure. Thus, some of the elongated condition of the severely strained, cold-reduced structure is retained. The pancake grain structure is associated with a drawing performance on critical applications superior to that of rimmed steel[3]. The ideal temperature for annealing is just below the Ac_1 (1,330° F.), but at this temperature there is a distinct possibility of sticking together of wraps of the coil. In addition, the solubility of carbon in ferrite at 1,300° F. (704° C.) is stated to be about 0.02 per cent; if the Ac_1 point is exceeded further carbon is taken into solution in Austenite. These dissolved carbides on cooling may form massive carbides or pearlite at the grain boundaries with consequent inferior mechanical properties. Coarse carbides may also give troubles on enamelling and hot-dip tinning applications.

Because of the dangers of sticking and coarse carbides the temperature for E.D.D. steel is generally below 1,300° F. (704° C.) a typical annealing cycle is[6]:—

30 to 40 hr. heating—depending on charge weight.

12 to 32 hr. soak at 1,250° F. (677° C.)—depending on the difficulty of the job.

60 hr. cooling to 200° F. (121° C.).

The annealed coil is removed from the annealing base when the temperature is below 200° F. (120° C.) and is then allowed to cool to room temperature before skin passing. Large fans are frequently used to reduce the cooling time between annealing and temper rolling. It is extremely important that coils are quite cold (below 75° F.) when temper rolled. The rate of strain ageing will be accelerated if coils are temper-rolled while warm, the actual rate of ageing will, of course, depend upon the temperature. Annealing can be carried out in coil form or sheet form, nowadays the bulk is coil annealed. Sheet annealing is normally employed for material which is required in the non-skin passed condition. This is because uncoiling after annealing gives rise to coil break (*i.e.* discontinuous yielding) which can be rectified only by temper rolling.

Surface Defects

Sand pits and discoloration are important surface defects introduced by annealing. Sand pits are caused by lack of positive pressure within the inner cover causing particles of sand from the seal to be drawn onto or into the coils. These sand particles may be rolled into the surface during temper rolling.

If oxygen or any oxidizing gas contaminates the neutral atmosphere then the sheet surface may be oxidized and a blue colour results instead of the desired bright surface finish. Stripping too early may give rise to straw coloured sheets.

Modern Developments in Annealing Practice

There are two methods of improving the production rate in the annealing operation, the first method is to build larger furnaces and thus be able to process greater tonnages during one cycle of operation. The other method is the use of a small charge with a fast furnace time. This is the principle used in the development of the single stack coil furnace where charges of 60 to 90 tons of steel are annealed with a short furnace cycle.

Multiple-stack furnaces, because of their construction, may have an uneven heating rate within individual coils as well as within each stack of coils. In single-stack furnaces, a faster and more even heating of the charge is possible, with the result that shorter cycle times are possible. The hardness and grain structure of the single stack furnace product is more uniform than that from multiple stack furnaces.

Continuous Annealing

Continuous annealing is widely used for the annealing of steel for tinplate.

A typical temperature time cycle for the continuous annealing of steel for tinplate is(7):—

1. Heating from room temperature to 1,200° F. to 1,350° F. (650° C. to 730° C.) (17 to 20 seconds).
2. Soaking at the annealing temperature (8 to 17 seconds).
3. "Slow" cooling from the annealing temperature (12 to 27 seconds).
4. "Fast" cooling from about 900° F. (480° C.) to just above room temperature (31 to 65 seconds).

Because of the thicker gauge, lower percentage cold reduction and the need for excellent ductility the continuous annealing of E.D.D. sheet presents special problems. Considerable research is in progress to develop a method of continuously annealing sheet to E.D.D. standards of ductility.

Open-coil Annealing

Open-coil annealing is rapidly extending in application. Because the wraps of the coil are separated, the inert atmosphere may penetrate between the wraps thereby considerably increasing the rate of heat transfer. Much faster heating and cooling rates and shorter soak times are possible than in the conventional box-annealing process. The product is uniformly annealed and, subject to steel base and hot-mill practice variations, has uniform ductility and grain-size. This process has many possibilities for making different qualities of steel, *e.g.* decarburizing and de-nitriding, etc. The manufacture of single-coat sag-resistant enamelling-grade steel by this process is already a commercial proposition. The possibilities of manufacturing non-ageing steel by decarburizing and de-nitriding during open coil annealing are being investigated.

Another important advantage of the process is that the sticking of wraps together cannot occur and as a result wrench marks are no longer troublesome.

Temper Rolling

Typical mechanical properties of annealed E.D.D. sheet are:—

In the annealed condition the pronounced yield elongation results in the formation of stretcher-strain ("Lüders lines") when the percentage extension during cold working is less than the percentage yield elongation (*i.e.* during a light draw or in the early stages of a tensile test). Stretcher-strain markings would still be visible after painting and are not permissible for parts where the surface finish is of importance, *e.g.* outside panels of motor-car bodies. The formation of stretcher-strain is closely connected with the yield-point elongation and in general the severity of the marking depends on the extent of the yield elongation. Fig. 12 shows severe stretcher-strain marking.

This yield elongation can be removed by temper rolling; Polakowski(8) has shown that the high residual stresses introduced into the sheet by the rolling process are responsible for masking the yield-point elongation.

If the temper-rolled sheet is stored at room temperature the yield elongation returns, together with the susceptibility to stretcher-strain formation. This return of the yield elongation is accompanied by an increase in yield strength, hardness and a decrease in ductility. These are the manifestations of strain age hardening. (The mechanism of the discontinuous yield point and strain-ageing of mild steel have already been dealt with in this series of lectures and so will not be discussed in this paper.).

If the steel has been stabilized with aluminium during steelmaking, strain-ageing does not occur and once the initial yield point is removed by

TABLE IV

Rb.	Y. Pt. (tons per sq. in.)	U.T.S. (tons per sq. in.)	Per cent. elong. 8 in. ($\frac{3}{4}$ in. wide test piece)	Olsen (20 gauge)	Per cent. Y. Pt. elong.
43	15	20	34	420	3 to 6

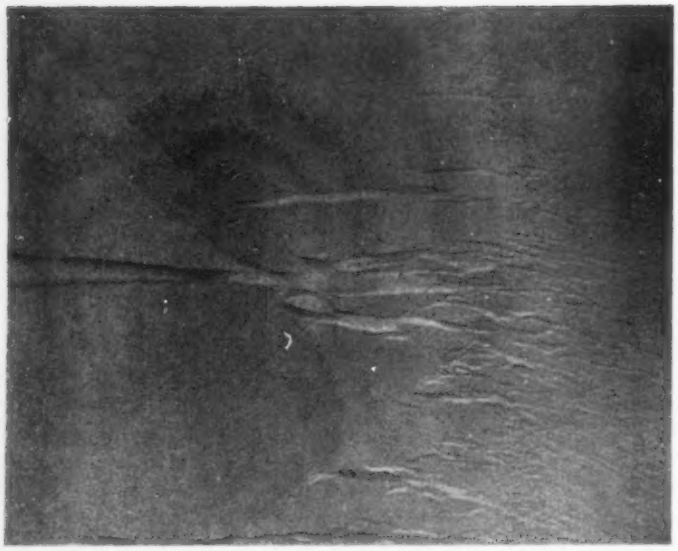


Fig. 12.—Stretcher-strains on non-skin-passed sheet

temper rolling it does not return on storing at room temperature. Storing rimmed steel at elevated temperatures accelerates the return of the yield elongation and the other manifestations of strain-ageing. Thus it is extremely important that:—

1. Temper rolling is carried out when the coil is cold.
2. That material is stored in a cool place (preferably refrigerated).
3. That the period between temper rolling and pressing is kept to a minimum.

The extension in length during temper rolling which successfully removes the yield point elongation (gauges 18, 20 and 24) is $\frac{3}{4}$ per cent. In practice $\frac{3}{4}$ to 1 per cent is normally specified.

The percentage temper rolling elongation is determined either by individual checks on each coil or by a continuous recorder. The individual checks are made by scribing the coil and measuring the distance between the scribe marks after rolling. Continuous recorders usually measure the speed of strip travel before and after rolling by means of various devices.

For research purposes X-Ray diffraction is frequently used to estimate the amount of temper rolling. The degree to which a metal has been cold worked can be estimated from the spottiness and diffusivity of the rings on an X-ray back-reflection photograph. Using a set of standard photographs taken from sheets which have received a known amount of skin passing, an experienced observer can estimate the degree of skin passing of any other sample by visual comparison of the X-ray photographs. (The accuracy of this estimation depends mainly on the accuracy of the standards).

The Effect of Temper Rolling on Mechanical Properties

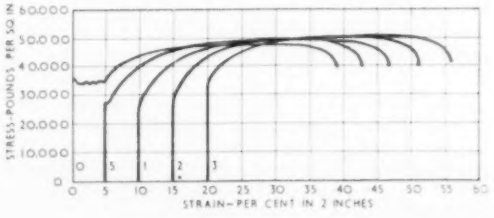
Small amounts of temper rolling have a very pronounced effect on the yield strength and yield elongation as shown in Fig. 13.

Temper rolling also increases hardness and reduces ductility but the effect is small when only $\frac{3}{4}$ to 1 per cent skin pass is given. Heavier reductions have more effect on hardness and ductility.

The amount of temper rolling also has an important effect on the rate of return of the yield elongation. In heavily skin-passed sheet the return of the yield elongation is slower than in lightly skin-passed sheet. However, the increase in hardness and loss of ductility due to cold work and subsequent strain-ageing is more severe in the heavily skin-passed material.

The normal commercial temper rolling for E.D.D. full-finish material of $\frac{3}{4}$ to 1 per cent is a compromise between these two effects. It is fortunate that up to $1\frac{1}{2}$ per cent yield elongation can be removed by flex roller levelling immediately prior to pressing.

Fig. 13.—Effect of temper rolling on mechanical properties



Effect of Temper Rolling on Surface Condition

The temper-mill rolls are normally lightly shot-blasted to give a matt sheet surface of 40 to 50 micro-inches C.L.A. which is acceptable for most purposes. For certain jobs, *e.g.* chromium plating, a very smooth finish is desirable.

A number of surface defects may occur on temper rolling material of poor shape. These are shape waves, spreader marks, feather marks and herring-bone. Incorrect rolling practice at the temper mill may contribute to the formation of some of these defects.

The temper-mill rolls may pick up grease or carbon deposit off the coils and subsequently mark the coil surface, care must be taken to avoid this occurrence.

Coil temper digs are quite common defects and are caused by slippage of the coil surface on the adjacent wrapped surface. This is sometimes due to the use of extreme back tension and sometimes to the failure of the mandrel to firmly grip the coils due to damage of the internal wraps.

Wrench marks are formed during temper rolling when sticking together of the coil wraps occurs. The formation of these marks may sometimes be minimized by increasing the back tension.

Under-skin-passing gives rise to stretcher-strains particularly at the coil edges.

Testing

Both simulative and non-simulative testing are discussed in the lectures by Wright [9] so it is not necessary for this paper to describe the processes and their interpretation.

Mechanical testing at Abbey Works is carried out on samples cut from near the end of the coil at the temper mill. Rockwell hardness, Olsen and tensile tests are carried out and if the results conform to the internal specifications the coils are released for cut-up, inspection and despatch. Where the tests fail to meet the specification the coil is "held" for further investigation. Some or all of the following information is collected:—

1. Pit chemical analysis.
2. Sheet chemical analysis.
3. Sheet microstructure.
4. X-ray diffraction (in the case of suspected over-skin-passed).
5. Results of re-tests.
6. Processing history. Hot-mill temperatures, percentage cold reduction. Annealing treatment, etc.
7. Ageing tests on rimmed steel.
8. Difficulty of the job and previous press history.

The coil is either rejected or passed on the basis of this information. Stabilized steel samples are given the Gensamer and Low test. Fig. 14 shows

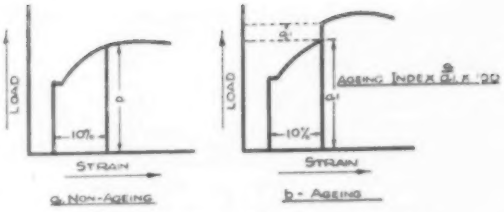


Fig. 14.—Method of obtaining ageing index

the stress strain curves of mild steel before and after straining 10 per cent. Curve B shows also the effect of ageing after straining 10 per cent. The increase in yield stress expressed as a percentage of the stress required to give 10 per cent elongation is known as the Gensamer and Low strain-ageing index, and for ordinary rimming steel is of the order of 16 to 20 per cent. Fully stabilized steels show no increase in stress following this treatment.

Ageing tests equivalent to one month's ageing are performed on a substantial proportion of S.C.O.W. E.D.D. rimmed-steel coils.

The coils are cut to sheets of the required length on the cut-up lines and $\frac{1}{4}$ to $\frac{1}{2}$ in. may be trimmed off each edge to give the ordered width. The sheet gauge is automatically checked by either flying micrometers or gamma-ray gauge meters. Surface inspection is carried out at the cut-up lines and hand inspection, defective sheets are diverted to different piles. There are more than 50 possible surface defects which would merit rejection of sheets.

The next processes are packing and despatch. The customer will assess the quality of the material and service by:—

1. The performance under the press.
2. The freedom from surface defects.
3. Adherence to ordered dimensions.
4. The arrival of the material at the required time in undamaged packs, of the correct weight and number of sheets, packed in the manner ordered by the customer.

The task of the quality-control department is to ensure that the ductility and surface condition of he product is at a consistently high standard. This is done by unrelenting attention to all the factors affecting quality already mentioned. In addition, fresh problems and difficulties constantly occur and it is another duty of the quality control department sometimes in conjunction with the research department to find a rapid solution to these new troubles.

Acknowledgement

The author wishes to express his thanks to the directors of the Steel Company of Wales Ltd. for their kind permission to publish this paper.

(*Continued in page 674*)

Quality Control in the Production of Steel Sheet—References

(*Continued from page* 673)

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The Quantitative Assessment of Deep Drawing and Stretch-Forming Qualities

(*Continued from page* 658)

punches and dies but only a 2-inch wide specimen. The die and clamping ring are reversible, each having a smooth side and a serrated side. The test is carried out first in the Erichsen fashion and then a further impression is made on the same sheet with the serrated faces tightly clamped. In the latter case the flange is prevented from drawing in and the depth of impression will be less. It is claimed that the difference in the depth of the two impressions expressed numerically gives useful information.

The Olsen test uses a $\frac{7}{8}$-in. diameter ball punch with die rings of 1 inch bore for sheet up to $\frac{1}{16}$ in. thick; $1\frac{1}{16}$ in. bore for sheet $\frac{1}{16}$ to $\frac{1}{8}$ in.; $1\frac{1}{4}$ in. bore for sheet $\frac{1}{8}$ to $\frac{3}{16}$ in.; and $1\frac{1}{2}$ in. bore for sheet $\frac{3}{16}$ to $\frac{1}{4}$ in. thick. The result is given by the depth of the impression in thousandths of an inch before fracture. The value is dependent on sheet thickness in a similar way to the Erichsen test, being relatively lower with thin sheets and higher with thick.

The Guillery test uses a sample 90 mm. square, tightly clamped in a ridge and groove arrangement, which is cupped with a 20-mm. diameter ball punch into a 50-mm. bore diameter die, and uses hydraulic drive for the punch.

(*To be continued*)

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Producing a Clicker Assembly

(*Continued from page* 648)

pass through it complete the work necessary for this detail.

The ejection of the shell is again accomplished by an ejector set in the lower bolster and operated from underneath by the action of a cushion, and if the degree of lift is restricted to allow the shell to be easily removed, it is sufficient to overcome any tightness that could occur should the location just grip the corner of the shell.

The final operations on this small assembly is outside the scope of presswork though the work of spinning over the rivets is occasionally associated with sheet metal production. However, prior to securing both details together the bore of the gear is internally ground to provide a housing for a ballrace, the design being a series of pads to grip the 5.375 in. diameter under the influence of air pressure while the wheel makes three or four passes through the bore. The spinning process then takes place securing the cover to the gear by six rivets, and it is preferable to perform this operation after grinding as it avoids dust clinging to the joint line made by the two joined parts.

Damage to the teeth during the initial production stages resulted from freeing the shell from the ring of scrap trimmed from the periphery and merely throwing them haphazardly into a wood box where continued rubbing against each other caused the teeth on many of them to become burred over. This problem was overcome by allowing the scrap ring to remain in position over the teeth where it was returned as the press ram reached the top of the stroke, and stacking the parts on trays with central wood locating pegs where they could not touch each other. While an accidental knock did remove the scrap from some details, it generally remained in place until the major work was completed. Lightly flame hardening the teeth was accomplished as a precaution against wear as the clicker passed across them, and, prior to final assembly, further parts are brazed to the gear by the furnace method to act as a driving medium.

INSTITUTE OF SHEET METAL ENGINEERING

ANNUAL AUTUMN CONFERENCE

THE Annual Autumn Conference of the Institute of Sheet Metal Engineering, with which will be associated the twelfth Exhibition of Sheet Metal Working Equipment and Techniques, will be held this year at the Imperial Hotel, Birmingham, on Tuesday, November 7, Wednesday, November 8, and Thursday, November 9.

Programme

Tuesday, November 7

11.30 a.m. Official opening of the 12th Exhibition of Sheet Metal Working Equipment and Techniques in the Connaught Room of the Imperial Hotel by E. W. Hancock, Esq., O.B.E., President of the Institute.

2.15 p.m. 1st Technical Session—**General Presswork.**
Paper: "Use of Dry Soap Film Lubricants for Deep Drawing" by J. Clarke (R. Cruickshank Ltd.)
Paper: "Tool Steels for High Speed Presswork" by A. W. F. Comley (Wilmot Breeden Laboratories).
Paper: "Methods of Rating Power Presses" by J. F. Kayser (Gillette Industries Ltd.)

Wednesday, November 8

9.30 a.m. 2nd Technical Session—**Problems of Feeding in Modern High Speed Presswork.**
Paper: "The Sprag Clutch as an Aid to Accurate Press Feeding" by E. E. Hempsall (Renold Chains Ltd.)
Paper: "The Swift Feeder Unit" by D. L. Dennison (Birmingham Tool and Gauge Co. Ltd.)
Paper: "Feeding of High Speed Hydraulic Presses" by D. E. Norton (Norton Tool Co. Ltd.)
Paper: "The B.N.F.M.R.A. Roller Stretcher Machine as an Aid to High-Speed Press Feeding" by D. Boxall (British Non-Ferrous Metals Research Association.)

1.00 p.m. Buffet Luncheon.

2.15 p.m. 2nd Technical Session (continued).
Paper: "Problems Associated with the Production of Aluminium Pressings for Bottle Closures" by W. H. Hadley (Metal Closures Ltd.)
Paper: "Development of Roller Feed Mechanisms for Coiled Strip" by H. F. Hawkins and R. J. Lloyd (Humphris and Sons Ltd.)

Thursday, November 9

9.30 a.m. 3rd Technical Session—**Feeding, Slitting and Processing of Heavy Wide Coils in Rolling Mills, Press Shops and Warehouses.** Discussion on this highly topical theme will be initiated by the presentation of five papers outlining the relevant problems and techniques from the following differing points of view:
1. The Steel Strip Producer.
2. The Aluminium Strip Producer.
3. The Equipment Manufacturer.
4. The Press Shop.
5. The Stockholder.

1.00 p.m. Buffet Luncheon.

2.15 p.m. 4th Technical Session—**Deformation of Metals at High Rates of Strain.**
Paper: "The Effect of Strain Rate on the Tensile Stress-Strain Characteristics of Metals, and some Practical Implications" by H. G. Baron (A.R.D.E.)
Paper: "The Rapid Determination of Strain Rate Effect Using a Dynamic Indentation Technique" by C. D. Davis and S. C. Hunter (A.R.D.E.)

Exhibition

The usual facilities will be provided for staging the Exhibition of Sheet Metal Working Equipment and Techniques, which has been a popular feature of the Annual Conference of the Institute for the past twelve years. A detailed programme and application form for tickets for the technical sessions will be circulated to all members in the near future. Non-members desirous of attending the Conference or of reserving space at the Exhibition, are invited to communicate with the Hon. Secretary of the Institute at John Adam House, 17/19, John Adam Street, London, W.C.2.

CO-OPERATIVE RESEARCH INTO THE COLD EXTRUSION OF STEEL

FOLLOWING the very successful Conference on the Cold Extrusion of Steel organized by the Institute of Sheet Metal Engineering at Sheffield, in November of last year, it was decided to circularize a questionnaire to all the organizations represented at the Conference, and other interested bodies. The object of the questionnaire was to determine to what extent organizations involved in the problems of cold extrusion were interested in a programme of co-operative research.

Coincidentally with this, the Institute was approached by the Department of Scientific and Industrial Research, concerning an International Co-operative Study of Metal Forming which had been submitted to the Committee of Applied Research of the European Productivity Agency. In soliciting the opinion of the Cold Extrusion Sub-Committee of I.S.M.E., D.S.I.R. posed four particular questions:

(1) Is an international co-operative study of any aspect of metal forming likely to be of value?
(2) Is the proposed programme suitable for co-operative research?
(3) Could a better programme of co-operative metal forming research be devised?
(4) To what extent might the experts' organization be prepared to participate?

In view of the excellent response to the questionnaire, and the need to give an objective reply to D.S.I.R., it was decided to invite representatives

(*Continued in page* 677)

Programme of 1961 Annual Conference

A MODERN TIN-PRINTING WORKS

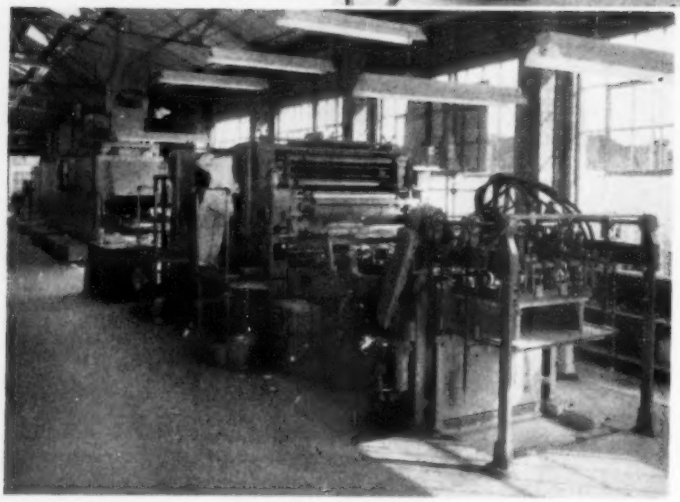

Fig. 1 (left).—The Crabtree "Marquess" Tandem metal decorating Press which has been installed in the McKenzie and Tapp printing line

Fig. 2 (above).—The parallel lines of the metal-decorating plant. On the right freshly-enamelled sheets are being delivered from the oven and the line on the left handles printing and drying

McKENZIE AND TAPP LTD., the metal box manufacturers of Eastern Avenue, Romford, have just put into operation one of the most up-to-date plants in the country for metal decorating. Formerly manufacturers only, the company's works have now been extended to enclose a complete shop for a continuous process of multi-colour printing, varnishing or enamelling, and drying.

The new installation includes the latest model of the Crabtree " Marquess " tandem metal decorating press.

This venture on the part of the Romford firm has been marked by considerable speed in building a new bay and installing the plant. The project was begun on January 1, 1960 when one wall of the existing works was dismantled. Foundations were laid and the new building erected by the beginning of May and, six weeks after, the whole of the coating and drying plant was installed. The "Marquess" was installed during the August bank holiday and, by the end of the first week in August, limited production was begun.

The Metal Decorating Line

The press chosen for the new plant was the latest version of the Crabtree "Marquess" tandem metal decorating press which is a straight-line or floor level design. It is, in fact, the first machine of its type to be put into operation in Southern England outside the various branches of the Metal Box Co.

The comparatively high speed of the machine—perfect register has been obtained at 5,000 sheets an hour—is due to the arrangement for forwarding the sheet towards the press and registering while still in motion. After the sheet has passed through for its first printing, it moves to a chain dog feed and is then re-registered positively in the second unit for the second printing.

(*Continued in page* 677)

A Modern Tin - Printing Works

(*Continued from page* 676)

A special feature of the press is that careful control of the moisture feed can be maintained under all conditions. The water-control potentiometer has its own motor directly above it and supply can be adjusted to a minimum. In addition, the machine employs Crabtree's seven damping roller arrangement, as against the orthodox five-roller. Under this design, the main feed goes direct to the first plate damping roller and surplus moisture is removed or smoothed out by the second damping roller.

The drive between the first and second unit of the tandem press embodies a clutch by means of which it is possible to run the two units independently and work on each at the same time for plating up, blanket hanging, roller washing or cleaning down.

The feeder on the press, apart from being designed for high speeds, also incorporates a pump which eliminates the possibility of lubricating oil mist contaminating the stock. A dry rotary pump designed by Lacy Hulbert, it has been specially designed for this feeder and uses graphite blades requiring no lubrication.

The Coating and Drying Line

A 36-in. by 24-in. feeder feeds a Dawson, Payne and Elliott spot coater suitable for either varnishing or enamelling. The roller on this machine is guaranteed to within 0.001 in. uniformity of surface and it is possible to apply film to a dry weight of 1 milligram per sq. in.

The oven is a convector heated conveyor oven which includes a number of modifications by the makers, Controlled Heat and Air Ltd. The panels have been increased to 4 in. from the 3 in. formerly used and the extraction machinery is of more efficient flow design. Temperatures within the oven are maintained and recorded within $\pm 5^{\circ}$ F. and the instrumentation is so arranged that any flame failure or interruption in the supply of gas automatically shuts down the complete plant.

Cooling after the sheets emerge is by means of three fans drawing air by shafts from the atmosphere outside the building. This is sufficient to give considerable flexibility to accord with ambient temperatures and the use of all three will give adequate cooling for the highest temperatures likely to be experienced in this country.

The unloader at the end of the line again includes recent modifications by the makers. Sheets can be delivered to the stacker face-up or face-down and there is a device beneath one of the delivery belts which causes sufficient "drag" on the sheet to prevent severe impact, and possible damage, against the stack buffers. In addition to this, two bars above the stack are fitted with a series of magnets which grip the sheet as it is delivered and which hold it temporarily in suspension. The moment the sheet edge makes contact with the buffers, the current generating the magnetic field is cut off and the sheet drops squarely on to the delivery stack. This device eliminates all possibility of the sheet dropping in to the stack at an angle.

The press feeds to a drying and offloading arrangement which is similar to that described on the coating line.

Institute of Sheet Metal Engineering

(*Continued from page* 675)

of interested companies and other organizations, to a meeting, to discuss these matters and to obtain an accurate consensus of opinion on the need for, and the proposed content of both national and international research programmes. This meeting was held in John Adam House, London on May 26th and both the attendance and the atmosphere of the meeting made it clear that considerable interest existed in research into the cold extrusion of steel.

As a result of this meeting, it was decided that:

(1) A co-operative study of metal forming on both a national and international scale was desirable, but in view of the work being carried out by such bodies as the International Deep Drawing Research Group, the proposed programme should cover only the cold extrusion of steel.

(2) Any programme drawn up for national research would, in the opinion of the meeting, be the best programme for international consideration, and such a programme should be drawn up based on the points raised during the meeting.

Proposals for a comprehensive programme of the matters requiring investigation has now been circulated to all the organizations represented at the meeting of May 26th and these organizations have been asked how, and to what extent they would wish to participate in carrying out this important research work. This programme is also being submitted to the Applied Research Division of the European Productivity Agency.

Whilst the Cold Extrusion Sub-Committee of I.S.M.E. has endeavoured to contact all interested organizations concerned with any aspect of the cold extrusion of steel, inevitably some such companies, research associations, technical colleges or universities will have been unintentionally overlooked. If any such organization is interested in joining this co-operative venture they can obtain a copy of the proposed research programme by communicating with: Mr. D. James, Hon. Secretary, I.S.M.E. Cold Extrusion Sub-Committee, c/o The Pyrene Company Limited, Metal Finishing Division, Great West Road, Brentford, Middlesex.

FOR OUR OVERSEAS READERS

(Continued from page 619)

Résumés des Principaux Articles

effectués sur une grande échelle sur différents diamètres et épaisseurs permettront de tracer des courbes qui, par interpolation, fourniront des renseignements utiles au personnel chargé de l'emboutissage profond. De plus, il démontre l'influence d'un nombre de paramètres tels l'épaisseur et la condition du métal, le rayon et la vitesse d'emboutissage ainsi que les raisons portant sur le choix du lubrifiant à employer pour l'essai.

Ce document a été présenté à une réunion mixte de l'International Deep Drawing Research Group et de la Société Française de Métallurgie.

Evaluation quantitative des qualités d'emboutissage profond et de façonnage par allongement—1 .. page 649

Par J. G. Wright, B.Sc., Ph.D., A.I.M., A.C.T. (Birm.).

Ceci est le premier des trois articles qui se fondent sur deux des conférences données par l'auteur et consacrées à "La métallurgie de l'emboutissage profond et du matriçage". Dans cet article, le Dr. Wright, tire au clair tout d'abord les divers procédés de façonnage, puis décrit les essais de qualité métallurgique générale, les essais quantitatifs non-simulatifs, les assais simulatifs et les essais d'emboutissage.

Contrôle de qualité dans la production de tôles d'acier pour l'emboutissage profond et le travail à la presse page 659

Par W. O. Thomas, A.I.M.

A la suite du développement rapide de l'industrie automobile au cours de ces 30 dernières années, il y a eu une demande croissante pour des tôles laminées à froid; cette demande a été satisfaite par l'augmentation rapide de la capacité des nouveaux laminoirs à feuillards. La forme de la voiture moderne demande des presses ayant une puissance et une vitesse supérieures et capables de produire des emboutissages plus profonds et plus compliqués. Ces emboutissages exigent à leur tour des tôles d'acier ayant une ductilité et une qualité de surface améliorées, donc un système de contrôle rigoureux de qualité, décrit de façon détaillée par l'auteur, est indispensable dans tous les stades du traitement depuis les matières premières jusqu'à la tôle finie.

Zusammenfassungen der Hauptartikel

praktische Versuche mit verschiedenen Durchmessern und Dicken Kurven gewinnen, aus denen der Tiefzieh-Ingenieur durch Interpolation nützliche Angaben erhalten kann. Der Verfasser zeigt außerdem den Einfluß einer Reihe von Parametern wie Dicke und Zustand des Metalls, Radius und Ziehgeschwindigkeit und gibt die Gesichtspunkte für die Wahl des Schmiermittels für den Prüfversuch.

Der Artikel gibt den Inhalt eines vor einer Gemeinschaftstagung der International Deep Drawing Research Group und der Société Française de Métallurgie gehaltenen Vortrages wieder.

Quantitative Abschätzung von Tiefzieh- und Streckformeigenschaften—1 .. Seite 649

Von J. G. Wright, B.Sc., Ph.D., A.I.M., A.C.T. (Birm.)

Der vorliegende ist der erste von drei Teilberichten, und den Inhalt zweier vom Verfasser in einer Sondervorlesungsreihe über „Metallurgie des Tiefziehens und Pressens" Vorträge wiedergeben. Im ersten Teil geht Dr. Wright, auf die verschiedenen Formprozesse ein und behandelt dann Prüfungen allgemein metallurgischer Art, direkte quantitative Prüfungen, modellmässige Prüfungen und Tiefungsproben.

Qualitätskontrolle bei der Herstellung von Stahlblech für das Tiefziehen und Pressen .. .. .. Seite 659

Von W. O. Thomas, A.I.M.

Das schnelle Wachstum der Kraftfahrzeugindustrie in den letzten dreißig Jahren hat einen gesteigerten Bedarf an kaltgewalzten Blechen zur Folge gehabt, der durch eine entsprechend schnelle Vergrößerung der Blechwalzkapazität gedeckt werden konnte. Die Formgebung des modernen Kraftwagens verlangt Pressen mit höherer Druckkraft und Geschwindigkeit, die tiefere und kompliziertere Fertigteile herstellen können. Diese Pressen benötigen ein Stahlblech mit verbesserter Formbarkeit und Oberflächenbeschaffenheit; aus diesem Grunde ist eine strenge Qualitätskontrolle, wie sie vom Verfasser eingehend beschrieben wird, in allen Herstellungsstufen vom Rohmaterial bis zum fertigen Blech unbedingt erforderlich.

Resúmenes de los Artículos Principales

y espesores harán posible la preparación de curvas que, por interpolación, proporcionen información útil para los que se dedican al estampado profundo. Además, muestra la influencia que ejercen un número de parámetros tales como el espesor y estado del metal, radio y velocidad de estampado y da las razones para la selección del lubricante para la prueba.

Este estudio fué presentado durante una reunión del International Deep Drawing Research Group y la Société Française de Métallurgie.

Avaluación cuantitativa de las cualidades para el estampado profundo y la formación por estiraje—1 .. página 649

Por J. G. Wright, B.Sc., Ph.D., A.I.M., A.C.T. (Birm.).

Es este el primer episodio de los tres de que se basan sobre dos conferencias dadas por el autor durante un curso especial sobre "La metalurgia del estampado profundo y el prensado" que tuvo lugar en la Escuela de Tecnología Avanzada de Birmingham. En este episodio, el Doctor Wright, empieza explicando los diversos procedimientos de formación y trata después de las pruebas de cualidad metalúrgica general, ensayos cuantitativos no simulativos, ensayos simulativos y ensayos de acopamiento.

Gobierno de la calidad en la producción de chapa de acero para estampado profundo y prensado .. página 659

Por W. O. Thomas, A.I.M.

Debido al rápido desarrollo de la industria del automóvil durante los últimos 30 años se ha creado una creciente demanda para chapas laminadas en frío, demanda que, a su vez, ha dado lugar al rápido aumento en la capacidad de los nuevos laminadores de tiras. La forma del automóvil moderno exige prensas de mayor potencia y velocidad para producir estampados más profundos y más complicados para los que es necesario contar con chapa de acero más dúctil y de mejor super cie que, a su vez, exige un sistema de control de calidad sumamente riguroso en todas las fases de la producción desde las materias primas hasta la chapa acabada, sistema que el autor describe con todo detalle.

SHEET METAL NEWS

FEATURING EVENTS AND PERSONALITIES IN THE INDUSTRY

BROMFORD IRON AND STEEL CO. LTD. OPEN NEW STRIP-ROLLING MILL

Large Coils Now Available

THE new rolling mill and fabric shop of the Bromford Iron and Steel Co. Ltd., West Bromwich, was officially opened on July 19 by The Rt. Hon. Frederick Errol, M.I.E.E., A.M.I.Mech.E., M.P., Minister of State to the Board of Trade.

The existing site of the Bromford Iron and Steel Co. Ltd. is hallowed ground in iron and steel circles. Bromford has had its ups and downs in past years, but generally Bromford Lane has not known a period since 1831 when metal work was not going on.

Earliest records dating to 1831 show that John Dawes took out a patent for pulverized fuel firing, but there is no record of its successful application. In 1835 John Dawes and Sons were working Bromford Ironworks and Oldbury Blast-furnaces, and four years later had two blastfurnaces at Oldbury averaging 65 tons per week forge pig. By 1866 John Dawes and Sons had the Bromford Ironworks, two blast-furnaces at Withymoor, Dudley, and also ironworks at Milton and Elsecar near Barnsley. In addition there were four blastfurnaces at Derby, Derbyshire, and three at Trent, Lincolnshire. Records show that by 1868 there were 60 puddling furnaces at Bromford. Ten years later, one of the sons, William Henry Dawes, died and the business was carried on by his widow, Elizabeth. By 1882 there were 63 puddling furnaces and seven mills on the site, but four years later the mortgagees took control and the works was closed. In 1887 Benjamin Scarf and Ezra Hadley trading as the Bromford Iron Company re-opened the works and in 1909 installed a six-stand continuous strip mill driven by a 1,000-h.p. steam engine.

The company continued until it ran down in the 1950's and was acquired by the present chairman, Charles Cooper, who immediately began a programme of equipment modernization.

The company now produce hot-rolled pickled and oiled strip from 10 s.w.g. to $\frac{3}{16}$ in. in widths of $\frac{3}{4}$ in. to 2 in. in coils or straight lengths and having a round or square edge. Steels in higher carbon ranges and also silico-manganese steel can be supplied.

Cold-rolled strip up to the high carbon range is made to a wide range of analysis and temper, in thicknesses from 0.01 in. to 0.25 in. and in widths from $\frac{3}{8}$ in. to $20\frac{1}{2}$ in. in coils or straight lengths, with bright or blue finish and having sheared, mill or rolled round edges.

The company state that they can supply to finer tolerances than B.S. if required, and will also produce to European and American equivalents. Another product is welded fabrics for concrete reinforcement to B.S.S. 1221.

New 4-high Mill

The new $8\frac{1}{2}$-in. and 20-in. by 26-in. four-high non-reversing mill was built by W. H. A. Robertson and Co. Ltd., and is capable of rolling steel strip from 0.080 in. to 0.156 in. thick, and from 8 in. to $20\frac{1}{2}$ in. wide. Of the very latest type, the mill supplements the company's existing capacity for cold-rolled strip, and will take total steel production up to approximately 5,000 tons per month.

The maximum rolling speed of the mill is 400 ft. per min., and it will produce coils in weight up to 5 cwt. per in. of strip width and 62 in. maximum outside coil diameter, *i.e.* to a maximum weight of about 5 tons. Feed to the mill is from a decoil box which takes the coils ready for rolling, and a feeding machine which is fitted with a pair of 5-in. dia. pinch rolls and a 5-roll leveller and a 5-in. dia. bending roll for removing the curvature from the strip as it uncoils.

Fig. 1.—Birlec heat-treatment furnaces installed at Bromford Iron and Steel Co. Ltd.

A Taylor, Taylor, Hobson E-type "Flying Mike" is fitted to the mill and at present gives a direct reading of thickness, but can be adapted to give full A.G.C. in the future if required. Electrics and electronics on the mill, including the M.G. set, are by Lancashire Dynamo. A 5-in. dia. bridle roll is also fitted on the outgoing side. In addition to the decoil box an expanding-type uncoiler is fitted to the ingoing side of the mill so that strip may be fed into the mill direct if required. Completed coils are pushed off the coiler onto a lift table which raises the coil to floor level and then tilts to eject the coil along a runway to a storage area. Rolling is effected with controlled tension.

A new Johannssen roll grinder has been installed for servicing the rolls.

To deal with the increased output from the new mill the existing heat-treatment plant has been augmented

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Bromford Iron and Steel Co. Ltd.

(*Continued from page* 679)

Fig. 2 (right).—General view of the Robertson 4-high mill at Bromford Iron and Steel Co. Ltd.

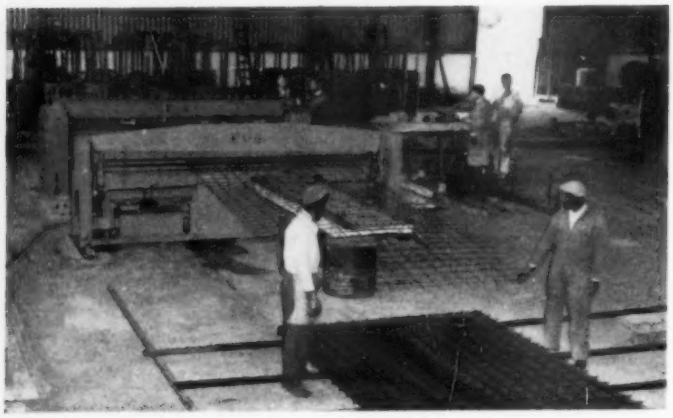

Fig. 3 (below).—View of part of the equipment for producing welded wire mesh

by the installation of four new Birlec inert-atmosphere bell furnaces using partially burnt town's gas.

Slitting Line

A new slitting line has also recently been installed. Built by Fred Cam (Engineers) Ltd., this consists of an uncoiler for wide hot-rolled coil (from 0.157 to 0.064 in. thick), a 5-roll roller leveller equipment which incorporates entry and pinch rolls, a rotary gang slitter and a re-coiler for simultaneously coiling the slit material (usually into four separate coils).

Welded Mesh

The production of welded mesh fabric for concrete reinforcement is a new venture for Bromford but is a diversity which has been planned for some time. It was necessary to erect a complete new factory, instal the latest machinery and this development has cost roughly £100,000.

The new factory, erected on land near the rolling mills, houses the entire equipment for production and is in two bays—one 200 ft. by 50 ft. contains the main mesh production line, while the other 100 ft. by 50 ft. is available for the stocking of material and preparation. In addition there is a loading bay and offices. The plant produces the complete range of wire mesh to British Standard Specification 1221 Part A, from the raw material which is hot-rolled steel rods in coil form.

The hot rolled rod is drawn into wire of gauge suitable for the mesh on a gravity block made by Sir James Farmer Norton Ltd., of Salford, Lancs. This machine, which has drawing speeds of 400, 600 and 800 ft. per min., will handle rod up to a maximum of ½ in. dia. and draw it to wire down to a minimum of 14 s.w.g. (0.080 in.).

Drawing is by the normal method but the finished wire is discharged below the machine which is mounted well above floor level. By this method it is possible to produce coils of one ton in weight. The operator is assisted in the removal of the coils by an air ejection mechanism, and it is possible to remove the coils and continue drawing in about half a minute. One-ton coils enable the welding machine to make longer runs. A mechanical scale-breaker which flexes the hot-rolled rod in two directions at 90 deg. to each other is provided, prior to the drawing and coiling equipment, through which the rod is fed continuously.

The wire coils are loaded on to turntables at the start of the mesh production lines and there are sufficient turntables to ensure that any number of main wires can be fed to one machine according to the type of mesh in production. The welding machine was manufactured by Entwicklung und Verwertung Gesellschaft of Graz, Austria, and is capable of seven main operations. There is a wire straightener, a cross wire feeding-mechanism, multiple electric welding heads, traction mechanism for drawing the completed mesh through the machine, edge trimmers and slitters, a cross shear for cutting the mesh into sheets, and roll equipment should the mesh be required in roll form instead of cut lengths.

When the main wires are fed into the machine they pass through the straightening rolls, and then beneath a feed hopper mechanism which places the cross wires in position.

COMPENSATION PLAN FOR EMPLOYEES AFFECTED BY "OPERATION SPEAR"

OVER the next five years, the Steel, Peech and Tozer branch of The United Steel Companies Ltd. will be replacing its 21 open-hearth furnaces by six 110-ton capacity electric arc furnaces. Known as Operation Spear, this development will give the works the largest electric steelmaking plant in the world. As a result of this major technical change, the labour force will be reduced by over one thousand men.

Some of these men will be retired and some will be redundant but it is hoped that redundancy will be confined to temporary employees.

Many of those who will have to change their jobs have given long and loyal service to the company. The company therefore proposes to pay some compensation for loss of status and earnings. Compensation will take the form of an *ex gratia* payment for loss of earnings brought about through these major technical changes in the steelmaking departments, taking into account three factors : loss of earnings, years of service, and age. The maximum payment to any one man will be £300.

It is emphasized that this scheme is designed as compensation for loss of earnings under quite exceptional circumstances.

Strip Mill Incorporates Flash-Annealing Equipment

A NEW strip mill which is devoted to the rolling of aluminium alloys has been installed at the Woodgate Works of Birmetals Ltd. This Sendzimir mill, believed to be the first of its type to be used for this purpose in Europe, rolls the alloy in coil form at 1,600 ft. a minute.

Working in conjunction with this new development is a flash-annealing furnace which will take sheets up to 8 ft. wide, or two 4 ft. wide sheets, side by side. This latter equipment was designed, manufactured and installed by G.W.B. Furnaces Ltd. of Dudley, Worcs. The furnace has four heating zones totalling 600 kW.

Effective dimensions of the furnace are : Loading length 6 ft.; heating chamber 40 ft.; cooling chamber 70 ft.; unloading table 6 ft.; width 8 ft. 6 in.; temperature 150 to 550°C.

G.W.B. designed this furnace to give a nominal throughput of two tons per hour although figures far in excess of this have, in fact, been achieved.

Heating chamber of the furnace is lined with high grade refractory brickwork backed by a thick wall of graded insulation to reduce heat losses to a minimum.

STAINLESS-STEEL SINK UNITS

THE first in a new range of stainless-steel sink tops is now being marketed by Andrews Bros. (Bristol) Ltd.

A feature of the new units is that they are formed from one sheet of steel. Special machinery had to be installed at the company's Liverpool factory before production could begin. In the past the tops had to be made in two parts, and the sink welded to the draining board and surround.

Eventually the new tops will be incorporated in Andrews Bros.' range of Elizabeth Ann kitchen furniture, as well as being sold separately.

The first size of top being produced measures 42 by 21 in.

RARE EARTH METALS

JOHNSON MATTHEY are now able to supply scandium, yttrium, and most of the fourteen rare earth metals in sheet form in thicknesses down to 0.001 in. and with a maximum width of 3 in. The sheet is available either cold worked or annealed.

This is the latest development in the company's production of the metals of this group, which have previously been available as ingots and in some cases as wire.

The company are also producing zone-refined tellurium of high purity. The total metallic impurity content, excluding selenium, is less than 5 p.p.m. and is normally in the region of 1 p.p.m. The selenium content does not exceed 5 p.p.m.

Further particulars are available on application to the company at 73-83, Hatton Garden, London, E.C.1.

Bromford Iron and Steel Co. Ltd.

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The latter are cut to length and straightened in a separate machine before loading into the hopper. The main wires are drawn forward in a series of steps beneath the welding heads which are carried on a cross beam. The beam makes a downward movement to bring the upper electrodes into contact with the wire cross points, the welding is completed and the beam then returns to its upper position. The welding heads can be very rapidly adjusted to suit the entire range of mesh sizes. The traction mechanism has a stepless stroke adjustment between one inch and 16 in. to cover the B.S.S. range. The slitting and trimming mechanism can be used to trim the ends of the cross wires and also slit the mesh up to a maximum of 8 ft. The cross cut flying shear is hydraulically driven and cuts the finished mesh into required lengths. If needed the shear can be left idle and the mesh is rolled on to a collapsible mandrel for delivery in rolled form.

Workers give up Holidays

More than 150 men at the works volunteered to give up one week of their annual holiday to help complete export orders. The works have been at full pressure to meet the orders, doing three eight-hour shifts a day.

The management asked for volunteers to go on working during the first week of their two-week holiday. Over three-quarters of the employees at the works offered to do so.

APPOINTMENTS and STAFF CHANGES

Mr. C. Pendry, formerly of Drummond Asquith, has been appointed sales manager of the newly-formed **Weldall-Grigg Machine Tools** organization, and Mr. R. A. Hammond of Charles S. W. Grigg Ltd. as assistant sales manager.

The central sales office will be situated in Stour Street, Birmingham and the London office at 65-67 Hanworth Road, Hounslow, Middlesex.

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The Brockhouse Organization announces the retirement of Mr. A. B. Gowan, Area sales manager (Steel Group) for the North East England and Scottish Areas. Mr. Gowan, who will continue to be available in a consultative capacity, is succeeded by Mr. R. Newbigin.

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Mr. C. R. Arnold, who has for over 10 years been on the technical sales staff of the **Vokes Group (George Vokes Ltd.)** has been promoted to the board as sales director.

A further appointment is also announced; that of Mr. Spriggs, who joined the company last year.

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Mr. R. W. Flux, A.M.C.T., M.I.E.E., has been appointed to the board of **Bruce Peebles & Co. Ltd.,** Edinburgh. He joined the company in 1952 as chief engineer of the Transformer Department, having served as transformer engineer in the Technical and Research Department of the C.E.B. and later in the Transmission Design Department of the B.E.A.

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Sir William Stanier, F.R.S., was re-elected President of the **Production Engineering Research Association** at the 16th annual general meeting of the Association held at Melton Mowbray.

The following were newly elected to the Council:

Mr. C. F. Barnard (executive vice-chairman of Mirrlees, Bickerton and Day Ltd.); Mr. C. G. H. Richardson (managing director of Ransome and Marles Bearing Co. Ltd.); Mr. J. R. Widdowson (research engineer of Samuel Fox and Co. Ltd.); Mr. A. J. Worster (production director of The Rover Co. Ltd.).

The following retiring members of Council were re-elected:

Mr. H. Gardner (director of Glenfield and Kennedy Holdings Ltd.); Mr. G. L. Hack (director of Bristol Siddeley Engines Ltd.); Mr. A. Siddall (director of Joseph Lucas (Electrical) Ltd.); Mr. J. B. Stevenson (divisional director of Electric and Musical Industries Ltd.); Mr. F. K. Lord (consultant of Standard Triumph International Ltd.).

At a meeting of Council following the annual general meeting, Sir Basil Tangye (Tangyes Ltd.), was re-elected Chairman of the Council and Mr. A. L. Stuchbery of The Metal Box Co. Ltd., and Mr. G. R. Pryor, chairman and managing director of Edward Pryor and Son Ltd., were re-elected vice-chairmen of Council.

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Mr. F. Holloway has been appointed secretary and office manager of the **Workington Iron and Steel Co.** branch of **The United Steel Companies Ltd.,** following the retirement of Mr. W. McGregor.

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Mr. C. Hipwell, director and general manager of **Redpath Brown and Co. Ltd.,** has resigned his executive appointments but will continue as a non-executive director.

Mr. John D. Bolckow, director and assistant general manager succeeds Mr. Hipwell as general manager.

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Mr. G. E. Chicken, commercial manager of Dorman Long (Steel) Ltd., and Mr. C. Hipwell, general manager of Redpath Brown and Co. Ltd., have retired from their executive positions on the board of **Dorman Long and Co. Ltd.** Mr. Chicken will continue as a non-executive director and Mr. Hipwell will remain a director of Redpath Brown and Co. Ltd.

New executive directors appointed are Mr. George Foster, general manager production, and Mr. Ernest N. Highton, general sales manager of Dorman Long (Steel) Ltd., both of whom became special directors of the parent company in 1959.

Mr. J. D. Bolckow, who succeeds Mr. Hipwell as general manager of Redpath Brown and Co. Ltd., is appointed a special director of Dorman Long.

British Executive and General Aviation Ltd. announce that Mr. John Nicholson has been appointed manager, Flight Operations, for the BEAGLE Group.

Mr. Nicholson, who is 39 years old, has been Chief Test Pilot of the de Havilland Engine Co. Ltd. since 1957.

* * *

British Insulated Callender's Cables Ltd. have appointed Mr. D. I. S. Hinton, B.A. (Mech. Science) as sales manager of BICC-Burndy Ltd., Prescot, Lancs.

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Mr. D. F. Campbell, chairman of **Davy-Ashmore Ltd.,** has announced his intention to retire from the board at the conclusion of the forthcoming annual general meeting. Mr. Campbell joined the board of Davy Brothers Ltd. in 1935 and became chairman of its successor, Davy-United, in 1944. Upon the merger with Power-Gas Corporation in 1960, Mr. Campbell agreed to continue as chairman of Davy-Ashmore Ltd. during the transition period.

Davy-Ashmore Ltd. have designated Mr. M. A. Fiennes to succeed Mr. Campbell as chairman and Mr. L. H. Downs will become vice-chairman. Mr. Fiennes is group managing director of Davy-Ashmore and will continue in that office.

While remaining chairman of Davy and United Engineering Co. Ltd., one of the principal companies in the Group, Mr. Fiennes has now relinquished his appointment as managing director of that company and Mr. M. F. Dowding has been appointed in his place. Mr. Dowding is already a director and was formerly general manager of the Machinery Division.

Major W. R. Brown, a former chairman of The Power-Gas Corporation Ltd., retired from that board prior to the merger in 1960, but joined the board of Davy-Ashmore to assist during the transition period. He will also retire at the conclusion of the annual general meeting, but will remain a director of Ashmore, Benson, Pease and Co. Ltd.

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The United Steel Companies Ltd. announce that Mr. Stafford Beer, who has been head of the company's department of operational research and cybernetics since its inception in 1957, has resigned to become managing director of a new international firm of operational research consultants based in London. Mr. David Owen, previously assistant head of the department, succeeds Mr. Beer.

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Appointments and Staff Changes

(*Continued from page 682*)

Mr. J. M. Brice, M.I.Prod.E., Mr. H. A. Chambers, M.I.Prod.E., and Mr. H. Rockwell, B.Sc., A.M.I. Mech.E. have been appointed directors of **Rockwell Machine Tool Co. Ltd.**

* * *

Hellermann Ltd., a subsidiary of the Bowthorpe Holdings group of companies, have appointed Mr. T. J. R. Smith as executive director.

Mr. Smith will be responsible for the exclusive handling of all Government, Ministry and Post Office Departments including the Admiralty, Army and Air Force.

* * *

Tempered Group Ltd., of Sheffield, announce two new appointments to the board of directors of **Henry Rossell and Co. Ltd.,** one of the companies recently acquired by the Group. They are Mr. John E. Gibb, until now establishment manager of Tempered Spring Co. Ltd., another member of the Group, and Mr. Kenneth G. Settle, A.A.C.C.A., secretary/accountant of Rossell's.

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British Executive and General Aviation Ltd. announce that Mr. Peter Brooks is to be appointed deputy managing director of the BEAGLE Group and a member of the BEAGLE board. He will take up his new duties as soon as his present commitments as fleet planning manager, British European Airways Corporation, can be concluded.

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Mr. Harry West, M.Sc., M.I.Mech.E., M.I.E.E., managing director of AEI (Manchester) Ltd., was installed as president of the **Institute of Welding** for 1961/62 at the recent annual general meeting.

Two new vice-presidents also took office at this meeting, Mr. C. Humphrey Davy, M.I.Mech.E. (director of Babcock and Wilcox Ltd.) and Mr. L. Redshaw, M.Eng., M.R.I.N.A. (deputy managing director of Vickers-Armstrongs (Shipbuilders) Ltd.).

The following have been elected to the Council of the Institute: E. V. Beatson, B.Sc.(Eng.), M.I.E.E.; M. Birkhead, A.Met., A.I.M.; V. W. Clack, A.M.I.Mech.E., A.M.I.Prod.E.; A. Evitts; S. H. Griffiths, F.I.M., M.I.S.I.; J. Hooper; J. McLean; R. Weck, Ph.D., M.I.C.E., M.I.Mech.E.

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Mr. Charles J. Baker has been appointed a director of **Ductile Steels Ltd.** and its subsidiaries. He has been employed with the company since 1940.

Mr. John T. McCarley, director of Manufacturing-International, has been appointed managing director of the British Division of **The Yale and Towne Manufacturing Co.**

Mr. McCarley succeeds Mr. John O. Sewell, who has resigned his position.

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Mr. J. A. V. Watson, O.B.E., will be appointed assistant managing director of **Castrol Industrial Ltd.** upon the retirement of Mr. W. F. List on January 1, 1962. Mr. Watson's appointment as an assistant managing director of the parent company Castrol Ltd., to take effect on the same date, has already been announced.

* * *

Mr. M. H. Gardiner, F.C.A., and Mr. C. Phillips, M.I.Mech.E., M.I.Prod.E., have been appointed joint managing directors of **Redman Tools and Products Ltd.**

Mr. A. M. Redman retains the chairmanship and there is no change of control, but this is to strengthen the organization, due to the company's greatly increased business.

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At the annual general meeting of the **British Welding Research Association,** Sir Charles S. Lillicrap, K.C.B., M.B.E., D.Sc., was re-elected president of the Council. The following retiring members of the Council were also re-elected: Mr. D. J. W. Boag, Dr. T. W. F. Brown, C.B.E., Mr. C. H. Davy, Mr. T. McIver, Mr. R. B. Shepheard, C.B.E., and Mr. J. M. Willey. Two new members, Viscount Ednam and Mr. W. Muirhead Watson were elected to the Council.

DOUBLE WIN

INGOT NEWS, published by Richard Thomas and Baldwins Ltd., has been awarded a Certificate of Merit in the 1961 house journal competition, organized by the British Association of Industrial Editors. This is the sixth award gained by Ingot News in national or international competitions.

A Certificate of Merit in the magazine category of the same contest has been awarded to *Ingot*, RTB's quarterly publication. This is the fifth award won by *Ingot*.

CHANGE OF ADDRESS

THE address of John Miles and Partners (London) Ltd., consulting engineers, is now Moor House, London Wall, London. E.C.2. Telephone: METropolitan 0471. Telegraphic Address: Milesco, Stock, London.

FURNITURE LINK

GRIFFIN AND GEORGE LTD. and Grundy Equipment Ltd. have been associated for several years in the manufacture and marketing of metal laboratory furniture and laboratory apparatus, including service racks, Griffin-Grundy ovens, Grundy solenoid valves, etc. A still closer link has now been forged whereby the Grundy Group becomes responsible also for the manufacture of wood laboratory furniture at their Cowley, Middlesex, and Mitcham joinery works. Marketing will continue to be handled solely by Griffin and George (Laboratory Construction) Ltd., whose sales department is at High Street, Cowley, Uxbridge, Middlesex.

The new organization provides a comprehensive service comprising, in one location, both engineering and wood-working facilities attuned to the specialized requirements of laboratory installations.

AGENCIES

F. J. EDWARDS LTD., 359-361 Euston Road, London, N.W.1, now represent in the United Kingdom Lefebvre Vaneste & Co., of Gullegem-Courtrai, Belgium, for their complete range of single-action, double-action and triple-action, double-sided hydraulic deep-drawing presses, their horizontal hydraulic bending and forming press generally known as "bulldozer", and open-fronted hydraulic drawing presses.

Also included in the representation are L.V.D. hydraulic guillotines and press brakes.

GORDON AND GOTCH LTD. have acquired the world distribution rights of the Alpine laminating machine. This machine can laminate sheets of any size up to the width of the machine and any length in a continuous action. It can be used for applying cellulose film to either cellulose film, Pliofilm or polyethylene; polyethlene to foil or paper; paper to foil. Glue is automatically-fed for double laminating action.

THE Slip Group of Companies have come to an arrangement for Monks and Crane Ltd., to be sole industrial distributors of all Molyslip products.

Monks and Crane, whose headquarters, showrooms and main depot are at Garretts Green Lane, Birmingham, 33, also have large depots in London, Bristol, Glasgow, Manchester, Leeds and Newcastle-on-Tyne.

NEW "CREEP" LAB. FOR E.R.A.

THE final decision by The British Electrical and Allied Industries Research Association to build a new office block at Cleeve Road, which was dictated by the need to move from Thorncroft Manor, coincided with the plan to build the new laboratory for research on steels for high temperatures on a site separated from the main laboratory. The possible use of common drains and access roads suggested that an economic arrangement would be to build the two as one unit.

The main reason for the isolation of the creep of steel laboratory was the requirement that it should be a windowless block with heavily insulated walls and roof so that internal conditions would remain steady. In addition the necessary heavy floor loading could only be economically provided for in a single-storey building.

It was necessary to limit the expenditure on building work, but to provide a very high degree of insulation from outside conditions as mentioned above and to introduce some form of air-conditioning which would maintain a reasonably constant internal temperature and deal with the very high heat emission from the creep furnaces.

It was decided to provide a clear floor span with lattice girders and a light structural steel frame, the roof to be of aluminium decking with cork insulation and three layers of felt covered with light coloured stone chippings to give some heat reflection. Additional insulation would be provided by an Asbestolux ceiling lined with a layer of Rocksil immediately below the roof decking. Ribbed aluminium sheeting would be used for the external walls, and lined internally with Asbestolux sheeting with additional insulation provided by a blanket of Rocksil hung in the cavity between the Asbestolux and aluminium sheets.

The sheeted walls stop approximately 4 ft. 6 in. above the floor, and 11 in. cavity walls consisting internally of lightweight concrete blocks and externally of dark purple facing bricks are provided below this level.

Concrete extract ducts are provided in the floor along the line of creep machines with chequer plate covers bedded in mastic. An adjustable outlet is provided under each machine together with a removable cover to allow for specimens from the furnaces to be removed.

As the building was to be windowless to avoid direct solar gain, a high standard of artificial illumination was necessary and continuous strips of fluorescent lighting were mounted immediately under the ceiling supported by a continuous service trunking.

The finish to the upper part of the walls and ceilings is provided by painted Asbestolux linings. All internal concrete block walls have been left fair-faced and painted. The floor is surfaced in granolithic concrete laid homogeneously with concrete sub-floor and painted with a special floor paint.

Eleven cubicles, for testing to destruction simulated steampipes under pressure, abut the end wall of the laboratory. The total area including these is 12,725 sq. ft.

AWARD FOR "NORAL NEWS"

NORAL NEWS, the quarterly magazine of Alcan Industries Ltd. (formerly Northern Aluminium Co. Ltd.) has been awarded a Certificate of Merit "for high quality of content and presentation" in the 1961 National House Journal Competition sponsored by the British Association of Industrial Editors. *Noral News* has received six awards altogether in the past few years, four of them in this annual British competition and two in the contest organised in the U.S.A. by the International Council of Industrial Editors.

Edited by Mr. G. G. Walker, Alcan Industries Publicity Division, Banbury, *Noral News* is produced for the interest of employees in all the company's works and offices.

EAST GERMAN —LOEWY ENGINEERING DEAL

A CONTRACT valued at approximately £1¼ million, for the supply of rolling mill equipment, has been signed by the Loewy Engineering Company Ltd., Bournemouth, a member of the T.I. Engineering Division, and D.I.A. Maschinen-Export of the German Democratic Republic (East Germany).

Negotiations for this equipment, which consists of extensive installations for the hot and cold rolling of aluminium strip and foil, were initiated in March during the Leipzig Spring Fair, and is intended for the East German non-ferrous metal industry; it will be installed in factories in the Leipzig area.

B.I.S.F. COMMENT ON STEEL PRICES

THE British Iron and Steel Federation has noted the Iron and Steel Board's decision to increase the maximum home trade prices of iron and steel products by 1 per cent.

The consequential increase in the industry's earnings is estimated at a rate of £7.5 million a year over the second half of 1961. Over the same period, additional costs are estimated at a rate of about £25 million a year net, after taking into account all expected savings from greater efficiencies.

The determination of prices is a matter for the Iron and Steel Board. The industry considers the increase now given to be totally inadequate having regard to the recent additional cost burdens on the Industry.

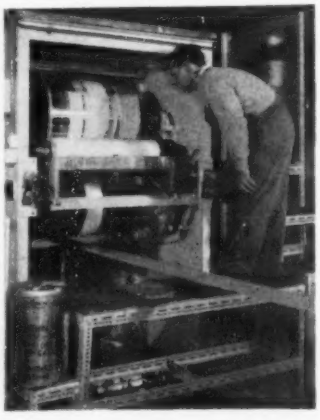
SLOTTED ANGLE ASSISTS PRODUCTION OF PAINTED STRIP

TAILOR-MADE access equipment in Dexion slotted angle is being used in connexion with a significant new paint process by Metalon Steels Ltd. of Willenhall.

Pre-painted metal strip is helping to increase productivity in a multitude of industries where such strip is an essential raw material. Various metal finishes, in a variety of colours, are thus made available for fabrication immediately. Like the Dexion slotted angle, a large percentage of the labour is already built into the material.

Dexion access equipment forms an inspection platform for the paint roller. The roller actually travels in reverse direction to that of the strip, thereby ensuring a maximum paint flow

(Courtesy of I.C.I. Ltd.)



ALCAN TO DOUBLE CANADIAN SHEET FABRICATING CAPACITY

ALUMINIUM LTD. state that their capacity to roll aluminium sheet in Canada will be doubled in the next eighteen months through the construction of a new modern sheet mill at Kingston, Ontario.

An expenditure of about $11,000,000 will be made by the company's subsidiary, Aluminum Co. of Canada, Ltd. The new mill, capable of rolling wider sheet and plate and larger coils than have hitherto been available from Canadian sources, will double Alcan's sheet capacity to 60,000 tons a year.

NEW FILE FACTORY IN PORTUGESE EAST AFRICA

MOCAMBIQUE Barclays Bank D.C.O. report that a file factory has recently been established in the outskirts of Beira. It is equipped with modern machinery permitting a daily manufacture of 200 dozen files of every type used in industry. Besides the manufacture of files, this concern will also engage in tempering spare parts for all purposes, and in supplying chemical products for tempering and cementation.

MILK MARKETING BOARD ORDERS NEW TANKERS

THE Milk Marketing Board has placed an order worth about £15,000 for six 1,750-gal. stainless steel tankers from Andrews Bros. (Bristol) Ltd., of Liverpool, for the bulk collection of milk from farms. They will be mounted on Albion Clydesdale chassis. The tankers will incorporate a system of vacuum filling, and the milk will be drawn into the tanks under vacuum rather than by the original methods of mechanical pumping.

£132,000 Order for Control Centres

BROOKHIRST IGRANIC, a company in the Metal Industries Group, has received orders from John Lysaght and Company and A.B. Svenska Flakfabriken for the supply of motor control centres for the new Ford Motor Company works at Halewood, Lancashire.

The orders are valued at £132,000.

Cabling of motor, control and distribution circuits from the individual starters will be carried out by Malcolm and Allan, another company in the Metal Industries Group.

NEW WELLMAN SUBSIDIARY COMPANIES

THE WELLMAN SMITH OWEN ENGINEERING CORPORATION LTD., announce that due to the expansion of their activities they have decided to segregate and operate the sales organizations of their divisions dealing respectively with cranes and mechanical handling equipment and rolling mill equipment as separate subsidiary companies under the titles of Wellman Crane and Machine Co. Ltd., and Wellman Rolling Mills Ltd., both of Parnell House, Wilton Road, London, S.W.1.

Mr. J. N. Rees, general sales manager (Mechanical Division) of the Corporation, has been appointed managing director of Wellman Crane and Machine Co. Ltd., the board of which also includes Mr. V. Bellingham, Mr. D. E. Pope, Mr. J. H. Knight, Mr. W. R. Robertson, Mr. S. W. Taylor and Mr. E. H. Dickson.

The board of Wellman Rolling Mills Ltd., will consist of Mr. Cyril Brooks (managing director), Mr. V. Bellingham, Mr. G. W. Clamp, Mr. R. Curdie, Mr. D. H. Goodreid, Mr. R. C. Lees and Mr. A. V. McCumiskey.

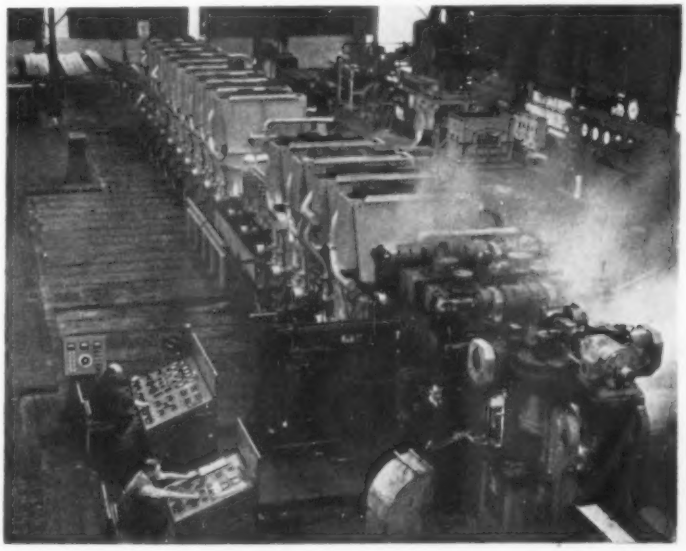
The operations of these subsidiary companies will be supported by the full engineering and manufacturing resources of the Wellman Group for the design and construction of cranes and handling machinery for the metallurgical and other industries, and for the design and construction of rolling mill equipment including continuous pickle lines, strip processing lines, etc., and also seamless tube-making plants.

FURNACE LINE ENLARGED FOR INCREASED OUTPUT AND CONVERTED TO OIL FIRING WITHOUT LOSS OF PRODUCTION

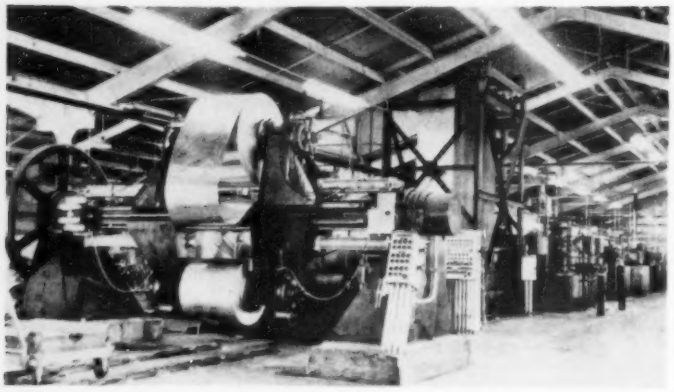
THIS high-speed heating line works in conjunction with a Sendzimir planetary mill rolling stainless-steel and high-carbon steel. Output has been increased from 9 to 15 tons per hour by extending the furnace line and converting to distillate oil firing using Incandescent R.I.M.P.A. high-intensity burners.

The plant was installed by Incandescent Heat Co. Ltd., at J. J. Habershon and Sons Ltd., Holmes Mills, Rotherham, in 1955 to heat steel slabs (maximum size 15 inches wide, 30 feet long, 1¾ inches thick) in a single pass through the furnace. They are then reduced to a strip 0.08 inches thick by the planetary hot rolling mill. Ten gas fired furnace sections were placed side by side so that the strip of metal would pass through them to be heated. Now an equalizing tunnel and four furnace sections have been added to the line.

(Courtesy of J. J. Habershon and Sons Ltd.)



A NEW INDUSTRY FOR THE NORTH-WEST



REPRESENTATIVES of local newspapers recently visited the headquarters of T. and T. Vicars Ltd., designers and manufacturers of biscuit and bread-making machinery, at Earlestown, Lancs. Their host was Henry Simon Ltd. (a company of Simon Engineering Ltd.) who had called the press conference to announce its decision to manufacture the Simon-Waldron range of web coating machinery at Vicars, a sister company.

The visitors examined a 12-ft. long model of coating plant for metal strip, actual size 300 ft., which was also shown at the Interplas Exhibition at Olympia.

The manufacture of Simon-Waldron machinery would provide new employment for about 50 engineers and draughtsmen and 250 factory workers.

PLASTICS DEVELOPMENTS

CASTROL LTD. has entered into contracts to acquire 75 per cent of the share capital of Melwood Thermoplastics Ltd., Harpenden, and the entire share capital of Tensile Products Ltd.

Mr. A. W. Meldrum will retain a financial interest in Melwood Thermoplastics Ltd. and will continue as managing director of that company and Tensile Products Ltd. Mr. A. G. T. Fryer and Mr. A. E. Chambers will remain on the board of Melwood Thermoplastics Ltd.

Melwood Thermoplastics manufacture high-grade thermo-plastic extrusions for use in a wide variety of industries and the company's production facilities are being extended to meet the growing demand for specialized plastic products.

Tensile Products Ltd. concentrate on the production of plastic fabrication and also provide a finishing service for the customers of Melwood Thermoplastics Ltd.

CHANGE OF COMPANY NAME

THE name of Radio Heaters Ltd. has been changed to Radyne Ltd.

FROM RIVETING TO WELDING

OVER the past year Cochran and Co., Annan, Ltd., Dumfriesshire, makers of vertical riveted boilers, have been changing their fabrication methods and are now using British Oxygen equipment for plate preparation for automatic electric welding. All-welded boilers and pressure vessels are now in full-scale production. Savings of 40 per cent. in time and labour are being made compared with mechanical methods of preparing the plates.

For plate preparation an Oxyplane machine is used and it is the first of its type to be used by boilermakers. The Oxyplane, with propane fuel as gas, gives a double-bevel and nose preparation to plates up to 40 ft. long, 10 ft. wide and 2 in. thick.

In the new pressure vessel shop, plates, after being rolled, are welded with a B.O.C. "Ram-Type" automatic welding boom, the latest equipment in its field. The boom has a welding length of 17 ft. and a vertical lift of 16 ft. At the base a fixed roller-bed rotates the boiler as it is welded. The machine uses the Unionmelt submerged-arc welding process.

SILVER JUBILEE OF DUCTILE STEELS LTD.

ON June 24 Ductile Steels Ltd. of Willenhall, Staffs, celebrated their Silver Jubilee as a public company. They started as a private company in 1932 and were originally formed from the resources of two companies of stockists and merchants, for the purpose of manufacturing cold-rolled steel strip.

Ductile Steels Ltd. itself is now a holding company for ten subsidiaries, manufacturing not only cold-rolled steel strip but also hot-rolled steel strip, hot-rolled bars and sections, steel tubes, cold-formed sections, electro-galvanized, plastic-coated and painted strip, power presses and tubular fabrications—especially tubular car seat frames. The first production planetary mill in the world was installed by them, and now operates as a separate subsidiary company, Ductile Planetary Mill Ltd. In addition they are also one of the largest stockists of steel sheets in the country, being an Accredited Stockist for the Steel Company of Wales Ltd.

An idea of the growth of the company can be obtained from the fact that in 1936 they had 60 employees and in the first year made a trading profit of about £25,000, whereas last year they had over 1,200 employees and made a trading profit of over £1 million.

SCHOFIELD TRAVEL SCHOLARSHIP

THE Council of the Institution of Production Engineers announces that the Schofield Travel Scholarship scheme ceases forthwith, and that it is being replaced by a Bursary of £600 per annum, tenable at a U.K. University for post-graduate studies in production engineering.

The figure given includes fees and the Bursary will be tenable for the first time for September-October, 1962 entrants.

It is required that applicants must (*a*) hold a first degree in Engineering or a Diploma in Technology (Eng.); (*b*) have fully discussed his proposed course or work with the University of his choice; and (*c*) have been accepted by the University.

Further details of the Bursary, giving procedure to be adopted by applicants, will be published later in the year.

U.K. U.S. FORM BRITISH COMPANY FOR ADVANCED AUTOMATION

THE General Electric Company Ltd. of England and Thompson Ramo Wooldridge Inc. (T.R.W.), of Los Angeles, have formed a new joint British company—with headquarters in London—to market industrial process control systems in Great Britain, the European Free Trade Area and the Commonwealth. The new company—International Systems Control Ltd.—will start with a capital of £430,000 equally shared by the parent companies.

The members of the Board of the new company, I.S.C. Ltd., are: Chairman: Mr. O. W. Humphreys (Technical Director of G.E.C.); managing director: Dr. D. N. Truscott (previously general manager, Electronics Division, G.E.C. Telecommunications Group); deputy managing director: Dr. E. M. Grabbe (Senior Staff Consultant on Automation (T.R.W.); directors: Mr. G. W. Fenimore (Vice-President, T.R.W. International); Mr. W. A. C. Maskell (Managing Director, G.E.C. Telecommunications Group), and Mr. M. E. Mohr (Vice-President, Electronic Systems and Equipment Group, T.R.W.).

T.R.W's contribution is to provide "know-how" of process control systems including computer designs, and G.E.C. is making available relevant patents, key personnel and in particular its advanced electronic engineering resources, and its experience and extensive facilities for the manufacture of precision electronic equipment.

International Systems Control Ltd., will apply the knowledge and experience of both partners in designing the control system for each process. The R.W. 300 system incorporates the first computer specifically designed for the completely automatic control of industrial processes. In addition to controlling the physical conditions, such as the flow of materials, temperatures and pressures, the computer does a variety of related recording tasks to cover the whole system.

CONTRACT ANNOUNCEMENT

YORKSHIRE IMPERIAL METALS LTD., has ordered a sectional cooling chamber, costing £3,000, from the Liverpool firm of stainless-steel fabricators, Andrews Bros. (Bristol) Ltd. It will be used in the production of copper tubing.

A TOUGH ASSIGNMENT

A DIFFICULT and tricky stud-welding operation using Crompton Parkinson equipment has recently been carried out at the Birmingham works of James Booth Aluminium Ltd. The application was concerned with the welding of reinforcement steel to sheet piling in the 148-in. rolling-mill foundation for the extensions at the works.

Since the working of the rolling mill would cause a heavy vibration to be set up between the foundation and the piles, thus constituting a serious hazard, it was considered imperative to key the reinforced concrete foundation securely to the ⅜-in. thick piles, which had been driven round the majority of the 80 ft. × 100 ft. × 23 ft. excavations. ⅝ in. × 16 in. long plain pins were welded *in situ* to the piles which had been ground locally, and despite such handicaps as cleaning, the moving of scaffolding and waiting for craneage, a good rate of progress was maintained throughout the working day, an average of about 37 studs per hour.

As concrete pouring proceeds and the various reinforcements are fitted these stud-welded plain pins will be bent *in situ* round the various reinforcement rods, thus giving a secure bond between the piles and the reinforced concrete foundation.

The main contractor for the job is C. Bryant and Son Ltd., of Birmingham. Carter Worseley of Tipton, Staffs, are sub-contractors for the stud welding and the reinforced concrete design has been undertaken by British Reinforced Concrete Co., of Stafford.

Unusual Turbine-Generators for West Midlands Gas Board

ASSOCIATED ELECTRICAL INDUSTRIES LTD. are to supply the West Midlands Gas Board with an unusual back-pressure turbine-generator to be installed in the Board's Coleshill Gas Works near Birmingham. The unit will supply electrical power and process steam for the new Lurgi gasification plant at Coleshill.

Rated at 4725 kW. the turbine will be designed for the very advanced steam conditions of an initial pressure and temperature of 2500 lb. per sq. in., 940°F., and it will exhaust at 450 lb. per sq. in.

The turbine will run at 8000 rpm and will drive the generator running at 1500 rpm through single-reduction, single-helical hardened and ground gearing.

EBBW VALE TINNING LINE STARTS PRODUCTION

TINPLATE in coil form was produced for the first time on July 17 on the new electrolytic tinning line installed at the Ebbw Vale Works of Richard Thomas and Baldwins Ltd.

Initial trials had lasted only a fortnight. A further running-in period will be necessary before the line goes into full production. The line permits coating of up to 16 oz. of tin per basis box and can produce differential coatings on either side of the sheet.

NEW APPLIED RESEARCH LAB. FOR ALFRED HERBERT LTD.

NEARLY 500 of Britain's leading industrialists and other professional figures have visited the head works of Alfred Herbert Ltd., Edgwick Works, Coventry, to see the activities immediately engaging the attention of the Research and Development Departments of this company.

Of particular interest is the new premises for the Applied Research Department, an artist's impression of which is shown below.

Books for Your Library

Guide to Metallurgical Information: SLA Bibliography No. 3, Special Libraries Association, 31 East 10th Street, New York 3, New York. 96 pp. Price $4.00.

DESCRIBING more than 600 books, journals and other information sources in the field of metallurgy, it is the only bibliographical searching tool of its type. Updating Richard Rimbach's "How to Find Metallurgical Information", published in 1936 and long out-of-print, the coverage has been extended to include societies, trade associations, research institutes, government agencies and technical services concerned with metallurgy as well as books, periodicals, microforms, translations and theses. The scope is world-wide, and reference sources published within the last 20 years are emphasized, although some older material is listed. Three indexes-Author and Agency, Book and Journal Title, and Subject—make access to the bibliographical data very easy.

The Guide was compiled by members of SLA's Metals Division who are experts in the literature of process metallurgy, physical metallurgy, mechanical metallurgy, ferrous metals and non-ferrous metals. The work was edited by Elizabeth W. Tapia, Head of the Research Library of Eastman Kodak Co.

Comprehensive Guide to Factory Law, by Robert McKown. New and revised edition. 124 pp. Published by Chantry Publications Ltd., 63 Neal Street, London, W.C.2. Price 25s., postage 1s. 3d.

WHEN this book was first published in 1954 it received an immediate welcome from works managers, industrial safety officers, personnel managers, and others who are expected to carry out the requirements of factory legislation but who are sometimes daunted by the complex mass of Acts of Parliament, Statutory Instruments, and High Court decisions which make up the law.

In this book the requirements laid down in nearly a dozen different Acts of Parliament and more than two hundred Statutory Instruments, Certificates of Exemption, etc., have been arranged and indexed according to subject, so that the enquirer can quickly see exactly what the law requires in any particular matter. Reference is also made to High Court decisions which have cleared up doubtful points.

The new edition has been revised to include the provisions of the 1959 Factories Act, the Clean Air Act, the Thermal Insulation Regulations, and other recent legislation, including the latest Food Hygiene Regulations. A supplement supplied in the form of a loose sheet inserted in the book anticipates the new Factories Act which will come into operation next April and which, without changing the law in any way, will alter the section numbers under which many of the requirements are made; this supplement shows the section numbers of the present Acts and the numbers of the sections covering the same requirements in the new Act.

As in the original edition, a special chapter has been devoted to the responsibilities imposed on the factory occupier by Common Law. These requirements are wider in scope and more general in character than the requirements of the Factories Acts and in order to meet them the occupier will frequently need the sort of guidance that this book gives.

WELDING ENGINEERING 1962

THE Institute of Welding is organizing its first large-scale exhibition at Buxton next year, in connexion with its Spring Meeting there. Facilities in the Winter Gardens make it possible to expand the displays and demonstrations which have been features of recent Institute meetings into a specialized exhibition of welding and the allied processes and techniques—brazing, soldering, cutting, hard facing, metal spraying, manipulating, inspection, testing, safety.

The theme of the Spring Meeting is Welding for Power Generation. Nearly 30 papers, including several from other countries, have been specially written for this meeting, the dates of which are April 30 to May 4, 1962. Welding Engineering 1962, as the exhibition has been named, will illustrate the rapid progress of welding technology in this country, especially in meeting the challenge of modern power generation plant construction.

There will be special sections devoted to Research, Education and Publications.

NEW COMPANIES

"Ltd." is understood, also "Private Co." Figures — Capital, Names — Directors, all unless otherwise indicated.

GARAS WELDING AND ENGINEERING, 126, Greyhound Lane, S.W.15. June 12. £100. *Stanley Garas, Eileen Garas.*

HOLLOWARE SUPPLIES AND PRESSINGS, Forward Works, Hatton Street, Bradley, Nr. Bilston, Staffs. June 20. £5,000. *To take over business of manufacturers of fittings and pressings for the holloware trade carried on as "Holloware Supplies" at Bradley, etc. Jiles H. Halling, Joan M. Halling.*

SKILLPRODEN, 2, Baldock Road, Stotfold, Arlesey, Beds. June 22. £300. *To carry on the business of general sheet metal workers, etc. Edward A. Smith, Douglas S. Burgham-Wilson, Wm. J. P. Adams.*

F. and R. BELBIN, Exchange Buildings, Whitley Bay, Northumberland. June 22. £1,500. *To carry on the business of sheet metal workers and electrical, mechanical and automobile engineers, etc. Fred Belbin, Frank Belbin, Roy Belbin.*

SAVAIR PRODUCTS, Stafford House, Norfolk Street, Strand, W.C.2. June 23. £10,000. *To carry on the business of engineers, founders, smiths, machinists, manufacturers and patentees of resistance welding equipment, pneumatic and hydraulic equipment, etc. Andrew F. A. Powles, Christopher G. Tanner.*

DELTA ENFIELD ROLLED METALS. June 28. £1,700,000. *To take over the businesses of manufacturers and marketers of rolled copper and brass and bronze sheet and strip and shapes cut from sheet and strip carried on by (1) Earle Bourne and Co. Ltd., (2) Alfred Case and Co. Ltd., and (3) Enfield Rolling Mills Ltd. Directors not named.*

ALDRIDGE ROLLING MILLS, 8, George Road, Edgbaston, Birmingham, 15. June 28. £500. *David Gerzon, Gertrude Gerzon.*

BREARLEY WELDING AND FABRICATING CO., 177, Barnt Green Road, Kendal End, Barnt Green, Nr. Birmingham. June 30. £100. *Frederick L. Earl, Arangel Vuckovic, Peter R. Burman.*

WILSONS PRODUCTS AND SPINNING CO., 62, Bissell Street, Birmingham 5. June 30. £5,000. *To carry on business of general metalworkers, etc. Robert W. Hughes, Arthur W. Finck.*

POTTER AND MYNOTT, 486/7, Ipswich Road, Slough, Bucks. July 3. £5,000. *To carry on the business of sheet metal workers, etc. Cecil G. Mynott.*

From the Register compiled by Jordan & Sons, Ltd. 16, Chancery Lane, London, W.C.2.

Factory Heating-1

The space heating of factories by electrical means can be achieved in a variety of ways which will be dealt with in the next Data Sheet.

Before deciding on any form of factory space heating—whether by means of electricity or not—it is as well to have clearly in mind all the components of the total annual running cost, and not merely the fuel cost, of the heating installation.

They are:

(A) The cost of the fuel or the electricity,

(B) Interest and depreciation on the capital cost of the installation,

(C) Labour,

(D) The cost of running auxiliary plant such as fans and pumps,

(E) Maintenance,

(F) Insurance.

In comparing fuel costs it should be borne in mind that electric heat is refined heat and has had all the fuss, bother, dirt, and cost of the conversion of fuel into heat taken out at the generating station.

In arriving at the true figures for capital cost and depreciation, maintenance and insurance, those connected with such items as boilerhouse, chimney, fuel store and access road should be included; labour costs should include such tasks as ash disposal. None of these items occurs when electricity is used, although space will be required for the electric boiler and storage vessels in the case of the type (h) in the next column.

Electricity provides the ideal answer to the requirements of the Clean Air Act, the impact of which has introduced an important new factor during the last few years.

The following list gives the main types into which electric heating installations fall:

(a) High temperature ("infra-red") overhead heaters operating at near red heat.

(b) Medium temperature panels operating at surface temperatures of 400° to 600° F.

(c) Extended surface heating in the shape of floorwarming operating at temperatures up to 80° F.

(d) Oil and water filled radiators.

(e) Tubular heaters.

(f) Unit heaters.

(g) Storage block heaters.

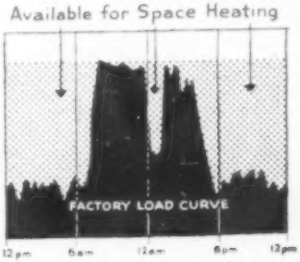
(h) Electric boilers and water heaters operating in conjunction with hot water radiators or panels either with or without water storage.

All these methods of electric heating can be divided into two distinct classes:

(a) Those that utilise electricity during "off-peak" hours and store the heat so generated for use at a later period.

(b) Those that use electricity whenever the heating system is in use (i.e. direct electric heaters).

The use of a heat storage system in a small works on a block tariff takes advantage of the lower tariff offered for an off-peak supply, and in the larger factory on a Maximum Demand tariff means that the heating load will not incur any M.D. charge. Alternatively



there may be cases where the use of direct electric heaters can be integrated with other factory loads in such a way that they are not used during the factory peak periods and will thus incur no additional M.D. charge.

For further information, get in touch with your Electricity Board or write direct to the Electrical Development Association, 2 Savoy Hill, London, W.C.2. Tel: TEMple Bar 9434.

Excellent reference books on the industrial and commercial uses of electricity and reprints of articles and papers are available. An example is "Higher Industrial Production with Electricity" (price 8/6 each or 9/- post free).

E.D.A. also have available on free loan in the U.K. a series of films on the industrial uses of electricity. Film and Book catalogues and Publications List sent on request. 14379-4

CUT HERE

NEW PLANT and EQUIPMENT

A monthly review of new machines, equipment, processes, etc., of interest to the producer and user of sheet metal

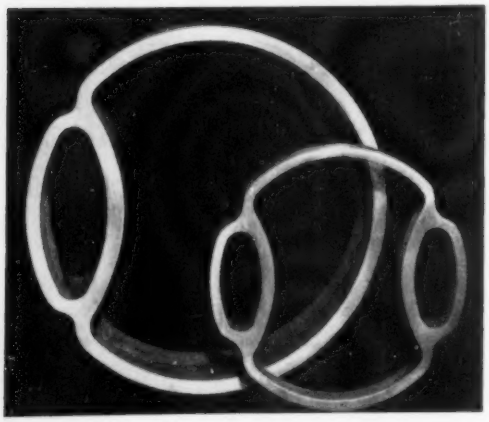
Extruded Aluminium Alloy Tube

IMPERIAL ALUMINIUM COMPANY LTD. are now marketing "Unitrace" tube in the U.K. 'Unitrace", manufactured by Aluminum Company of 'America, is designed for use in the processing of chemical and food products, where liquids—for example, tar, oil, fat, chocolate—must be kept warm to prevent solidifying when being pumped from one location to another. It is equally effective where liquids have to be kept cool at a controlled temperature.

"Unitrace" is an extruded aluminium alloy tube (Fig. 1) combining two integral channels, the larger for the product line, the smaller for the tracer line carrying the heating or cooling medium.

"Unitrace" is light and easily bent but has considerable strength and the integral construction provides excellent thermal characteristics. It is supplied in standard 30-ft. lengths and in seven standard sizes from 1 in. to 8 in. Outside diameter of the tube conforms to standard pipe sizes so that normal insulation can be fitted. Special flange fittings enable lengths to be bolted together by standard flanges or to jacketed fittings by means of adaptor flanges.

Fig. 1.—*Extruded aluminium alloy tube*



Tracecaps enable welded joints to be made on straight runs, tees and cross-connexions. Right-angle elbows having trace lines at the side, outside or inside, are available.

The range has now been increased by the addition of "Duotrace", with two tracer lines instead of one.

Multiple Turret Punching Presses with Co-ordinating Tables

THE Edel range of multiple turret punching presses with co-ordinating tables for multiple punching, with accuracy and economy, different sized and shaped holes in pre-cut switchboard and chassis blanks, is introduced by F. J. Edwards Ltd.

The table carrying the work clamps and material supports is sturdily built and finely balanced. Where necessary, multiple stop rail devices can be fitted for series production. The bottom slides give front-to-back movement, while the top slide, carrying the table, gives left-to-right movement.

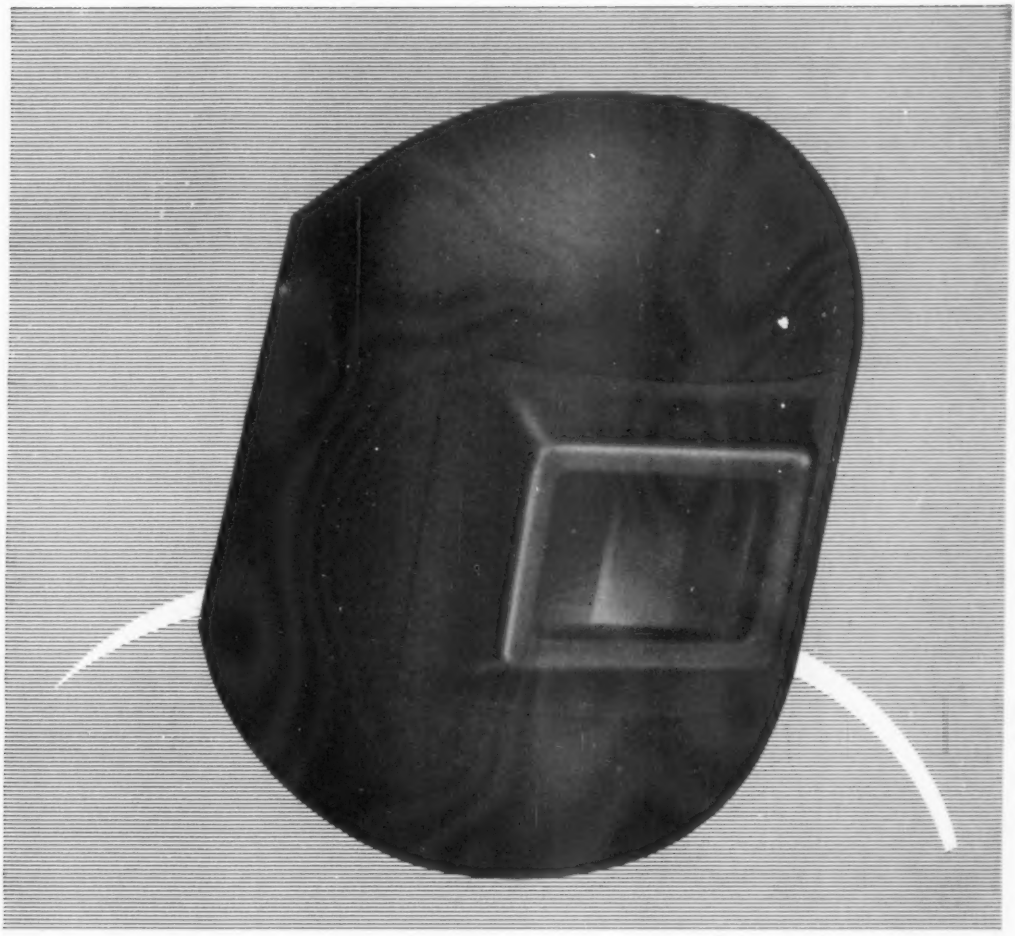
Co-ordinating rolling tables are available to suit each size machine and sheet to be processed. Control panels are fitted on the front of the table in the most convenient position for the operator.

The power head of the press is of sturdy all-steel fabricated construction. Drive is from a star delta motor to a balanced flywheel, through transmission shafts running in roller bearings to a completely enclosed gear reduction which drives the eccentric shaft operating the ram. The gear reduction equipment runs in an oil bath and the eccentric shaft is mounted in special bronze bearings. The ram is hardened and ground and the extra long ram guides are adjustable. The machine is controlled by a multi-tooth dog clutch which is also hardened and ground. The ram can be raised and lowered by a handwheel, with or without the motor running, so that the tools can be set easily and quickly.

On machines of up to 35 tons capacity, the turret is adjusted by hand. The head can be fitted with a telescopic rod enabling it to be swung from left to right. Machines of from 50 tons capacity upwards, are, however, fitted with very heavy turrets and are supplied with power movement only.

Standard turret locking mechanism is built into all machines. The turrets on all machines are easily manoeuvred for tool selection and accurately located and

(*Continued in page* 692)



The Right Helmet...

Most welders prefer Murex helmets because they are right for protection, comfort and strength. They are made of high grade fibre or bonded laminated plastic and are completely shockproof, light in weight and comfortable to wear. Each helmet is fitted with an adjustable headband having an automatic locking device which enables the helmet to be held in the "up" position as long as desired. A patent Murex glass holder provides a dual purpose facility in the plastic type. The coloured filter glass can be raised or lowered in a fraction of a second so that the welder can sight his work right up to the moment of striking the arc.

MUREX

Please write for full particulars.

MUREX WELDING PROCESSES LTD., WALTHAM CROSS, HERTS. **Telephone: Waltham Cross 23636**

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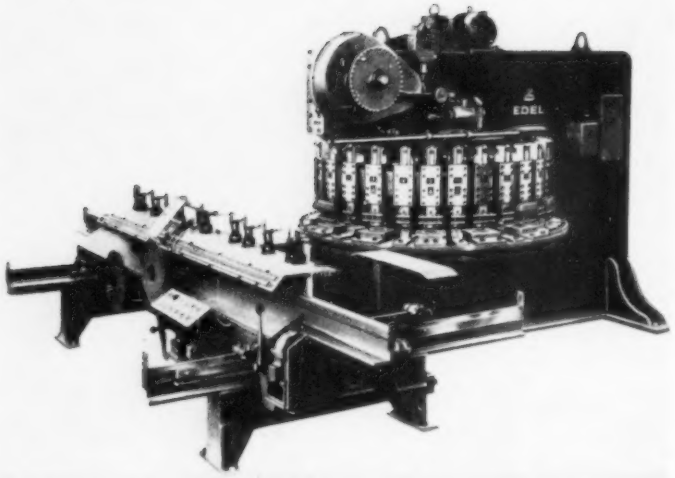


Fig. 2. (left).—Multiple turret punching press

Fig. 3 (below).—Press brake

locked in the exact centre of the ram, ensuring that the position corresponds with the co-ordinating dimension at zero. The turret housing is provided with a slide with a channel-shaped opening which encloses the stop of each station. The slide is disengaged from the stop by a lever.

On the power-operated turrets, the turret is released by the slide lever with one hand, while the other hand operates the right or left traverse push-button. The head is allowed to travel until the required tool is in position, then the stop is engaged.

A solenoid can be fitted, if required, to enable the locking mechanism to be released and locked from the co-ordinating table by push-button.

A safety slipping device is incorporated, ensuring that should the turret traverse button not be released, but the turret stop put into operation, the head will not jam up or damage the drive or motor.

To compensate for slight inaccuracies in tool making, provision is made for the stop of each station to be adjusted, left or right, enabling the tools to be used.

These multiple turret punching presses, fitted with or without co-ordinate table, template table or any other type of linear feed, can be supplied in a range of sizes, with capacities up to 100 tons, with 31 in. depth of throat and between 12 and 40 stations. Special individual requirements can be incorporated. The model illustrated is the RM100/650/32 (Fig. 2).

Distributors for Edel equipment in the United Kingdom are F. J. Edwards Ltd., Edwards House, 359-361, Euston Road, London, N.W.1.

Press Brake for Press Type Operations

THE utilization of added die lengths and widths available in press brake design is typified by this 9 Series by 10 ft. Cincinnati (mechanical) press brake (Fig. 3), manufactured by The Cincinnati Shaper Company, Cincinnati, Ohio, for *press* application. The machine develops 225 tons at or near the bottom of the stroke.

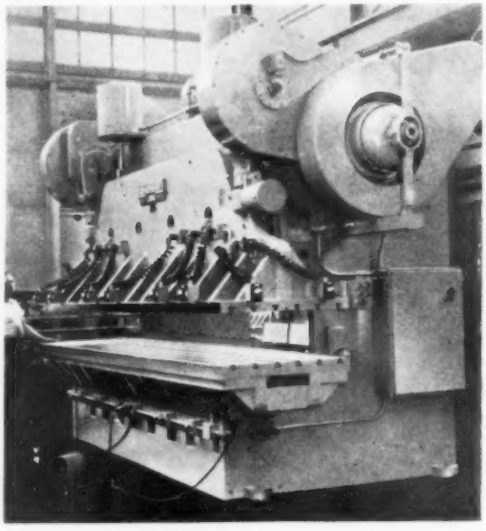
The 36 in. permanently widened bed and ram provide adequate back up for large die sets. In addition, the double plate bed is equipped with a shelf for the adaptation of die cushions for press applications requiring such units.

To facilitate the use of the overall die length, in this instance 14 ft. 0 in., the press brake is furnished with 12 in. extensions on both ends, the machine is provided with an 18 in. throat, lowered to clear the top rear corner of the 3¼ in. thick × 36 in. wide "T"-slotted bolster plate.

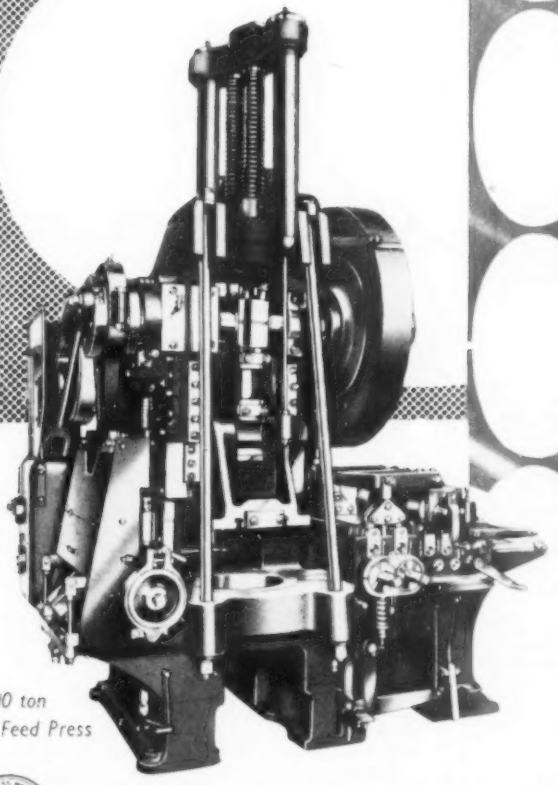
Operator safety, provided by palm buttons adaptable to either the bed, or the ram; 16 set up in series, receptacles for a total of eight possible operators, are tied in to an air electric clutch control so that all buttons must be depressed for machine operation.

Added features include remote control to the power ram elevation, 5 in. stroke, air counterbalances, tonnage load indicator, electro-magnetic brake on the ram adjusting motor, automatic ram stop at the top of the stroke with non-repeat feature and reversing control.

(*Continued in page* 694)



AUTOMATIC FEED PRESSES



100 ton
Roll Feed Press

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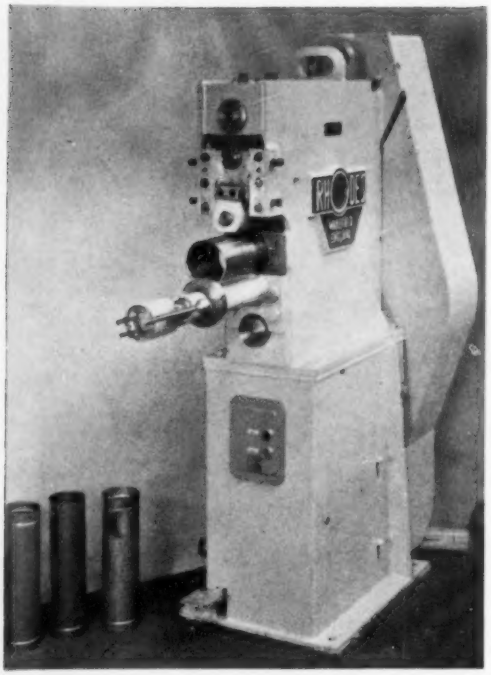

Fig. 4 (left).— Beading machine

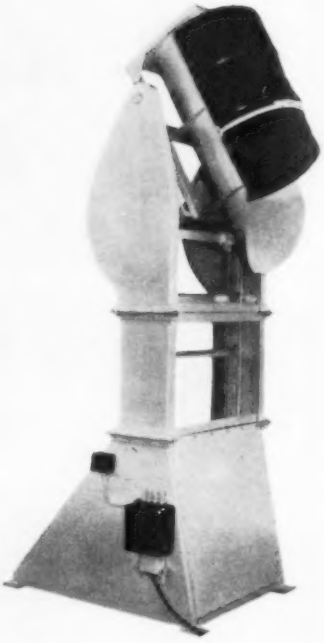

Fig. 5 (right).— Lifting and tipping machine

Special-Purpose Beading Machines

A MANUFACTURER had to produce an internal stiffening bead at approximately 1 in. from the end of a cylindrical lamp chimney. To meet these requirements, Joseph Rhodes and Sons Ltd., Wakefield, have designed a special new beading machine to carry out the operation expeditiously.

The workpiece (seen in Fig. 4) is placed on a mandrel and held by a quick-operating clamp. The beading rolls run continuously; depression of the treadle engages a clutch operating a cam motion which lowers the top rotating roller on to the workpiece. The necessary pressure is applied in four stages. At the end of the cycle, the roller returns to its starting position, and the workpiece is removed, leaving the machine ready for the repeat operation.

Machines of this type can readily be adapted to carry out beading operations on cylindrical objects of a similar nature, and Jos. Rhodes are prepared to offer designs suited to the requirements of any user.

Lifting and Tipping Machine

TO fulfil the need for a simple and reliable machine for lifting and emptying all types of containers, Russell Constructions Ltd., Russell House, Adam Street, London, W.C.2, have developed a unit which will lift any kind of container weighing up to 10 cwt. and tip it so as to empty the contents into a hopper, truck, mixer or other receptacle. This machine, known as the "Hi-Tip" has a minimum height of lift of 4 ft. 6 in. An interesting feature is the fact that vertical sections can be added to increase this dimension to any height desired.

It is fabricated of ¼-in. mild-steel of all-welded construction and consists of a base, a top unit and centre sections. The base, which for the standard machine occupies an area of only 3 ft. by 4 ft. 6 in., houses the electrical equipment, control mechanism, main drive and chain compensating device, all the mechanical parts being adequately protected.

The top unit contains the actuating cam guides for the tipping action, and the centre sections, which can be added or removed to alter the height of lift, include the appropriate lengths of guide rails. The machine is powered by an electric motor with a self-contained braking unit and the carriage is elevated by means of twin Renold lifting chains and sprockets. Automatic stop devices are fitted at loading and tipping positions and an overload switch is used to protect the motor.

The start and return operations are actuated manually but automatic sequence control can be provided if required, the emptying time being controlled by a variable time switch. The speed of lift is 30 ft. per min. and the standard tipping angle is 30 deg. from the vertical. The cradle can be adapted to take any particular type of containers such as drums, barrels, kegs, skips, trolleys, vats, bowls, sacks, etc., the chute being shaped to suit the material being handled.

Remotely-Controlled Colour TV Camera

A NEW camera, which could revolutionize the use of colour television, is now available from EMI Electronics Ltd., Hayes, Middx.

This camera, which can be sited in hazardous positions and controlled by an operator a thousand feet away, can televise true-to-life colour pictures from inside a steel furnace of the moment when a charge of metal reaches "white-heat", or tell a baker when his cakes are done to a turn—in both cases, without opening the door and losing valuable heat.

Colour pictures can be displayed on a 21-in. receiver or on large screen projectors up to 18 ft. × 12 ft.

(*Continued in page* 696)

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Fig. 6.—Welding pressure recorder

Resistance Welding Pressure Recorder

THE production of a satisfactory resistance weld is dependent upon four variables, the surface condition of the metal being welded, the current setting of the welding machine, the duration of the welding cycle and the pressure developed between the welding electrodes. The surface condition of the metal can be controlled by suitable preparation prior to welding. Most resistance welding machines are fitted with current or heat controls and suitable time controls. Apart from pneumatically operated welders, no machines are fitted with any recording unit to measure the pressure between the electrodes. The Presstotest recorder (Fig. 6) has been designed and developed to measure this pressure.

It is a small tool which can be held in one hand between the tips of the welder resting on the bottom tip and the centre of the plunger underneath the top tip. When the tips are brought together by means of the foot pedal on the machine the pressure developed is shown on the recorder dial in pounds.

The pressure required is related to the tip diameter which is determined by the thickness of the metal being welded.

The Presstotest is at present manufactured in pressure ranges of 0/600 lb. or 0/2,000 lb. both instruments are the same overall size. Minimum arm length required is $\frac{3}{4}$ in.; minimum tip gap $1\frac{1}{4}$ in.; overall length $5\frac{1}{2}$ in.; maximum width $2\frac{3}{8}$ in.; and the finish is polished lacquer and black crackle stove enamel.

The recorder is available from A. S. Young and Co. Ltd., Tower Works, Woodside Lane, N.12.

Flanging Presses and Bevel Shears

THE Pearson Machine Tool Co., of Walker, Newcastle-upon-Tyne, have introduced a new range of flanging presses in which the ram is returned to its top position by hydraulic power—instead of oil/gas accumulator as previously—which gives positive action facilitating the withdrawal of punches or deep dies when

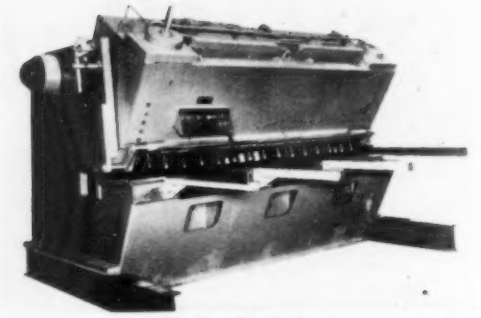


Fig. 7.—Bevel shear

used. Long hydraulic stroke s provided, with up and down stroke limitation, the latter with micro-setting, as a standard feature. Further, an electro-magnetic clutch is fitted between pump and motor so that the pump only runs while the press is stroking, thus minimizing wear and temperature rise.

The company also have a new range of bevel shears (Fig. 7). These machines are offered in $\frac{3}{8}$ in., $\frac{1}{2}$ in., 1 in. and $1\frac{1}{4}$ in. mild-steel capacities. In each case the length is 10 ft. 0 in. and a 12 in. deep gap is provided in the end frames enabling longer plates to be dealt with. The head of the machine, carrying the upper shear blade, is inclinable from 0 deg. to 35 deg., so that a bevel cut can be made at any desired angle. Furthermore, the rake of the upper blade is adjustable according to the thickness of plate under shear.

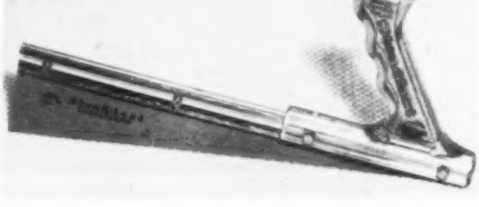
The source of hydraulic power in all Pearson machine tools is the well-tested multi-cylinder radial pump of their own manufacture. This is now available as a separate unit called the Pearson hydraulic power pack, which is offered in a range of capacities. Each power pack comprises motor, pump, oil tank, control valve, adjustable relief valve and pressure gauge and is thus a compact self-contained unit which needs only connexion to electric supply to provide a source of hydraulic power giving pressures up to 4,000 lb. per sq. in. at variable delivery.

Sheet Saw

THE "Steadfast" sheet saw (Fig. 8) is an addition to the range of tools manufactured by J. Stead and Co. Ltd., Sheffield, 2. The saw has a 12-in. triangulated blade of "Colbaltcrom" special abrasion-resistant steel and is held in a polished alloy spine to which is fitted a shatter proof plastic handle.

(*Continued in page 698*)

Fig. 8.—Sheet saw



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Electronic Die Saver

THE Radiovisor electronic die saver, for which J. Broughton and Son (Engineers) Ltd., Kings Norton Factory Centre, Birmingham, 30, act as agents, has been designed to prevent die damage by continually monitoring power-press operations and making sure that the component is ejected from the die before the press is allowed to commence the next stroke.

The unit may readily be installed on power presses :—

having mechanically-operated "dog", roller key or air clutch which can be converted for electrical operation;

where there are electrical initiation and electrical locking circuits;

where, with positive type clutches, the point of ejection allows the press to be stopped at T.D.C.;

where with each stroke of the press the metallic stamped part may be ejected through or near a detection head.

The unit consists of two parts (*a*) the control unit, (*b*) the detector head. The control unit is fundamentally a high frequency oscillator and an accurate fail-safe electronic timer. The control is connected to the detector head which is a carefully designed oscillator coil the inductance of which is disturbed by the close proximity of moving metallic components.

A range of detector heads is available to suit many standard conditions and component sizes. All Type "A" heads are 1 in. or less in thickness ; this permits mounting in restricted spaces. Heads for special purposes will be designed to meet individual requirements.

Each metallic stamped part passing through or over the detector head gives rise to an electronic signal which is fed to the control unit. This signal operates a relay which closes a set of normally open contacts, the relay remaining energized for a time period chosen to bridge the time interval between two components. As long as the electrical impulses are repeated within the set time interval the relay contacts stay closed. When an impulse is missed due to an ejection failure the relay becomes de-energized and its contacts open to disconnect the press control circuit and stop the press. A sensitivity control adjusts the electronic circuit to take into consideration the size of the stamped part in relation to the area of the detection head.

The unit will operate at a rate up to 180 impulses per minute and higher speeds can be accommodated if required.

Molytherm Grease

ROCOL Molytherm Grease has been developed specially to provide lubrication for industrial plant and machinery at a higher range of temperature than that of other high temperature greases. It is recommended for continuous service above 350° F., and withstands long periods above 450° F. and short periods up to 550° F., to lubricate many mechanisms previously lubricated only by silicones. It contains molybdenum disulphide to ensure its lubricating ability.

Based on a high flash-point oil and a non-soap thickener which is unaffected by heat or chemicals, Rocol Molytherm grease is soft enough to be applied through grease cups or nipples. It is claimed to be resistant to steam and water, and to show considerable resistance to the stripping action of solvents and vapours.

The product is available from Rocol Ltd., Rocol House, Swillington, Leeds.

Roll Tube Straightening Machine

THE Bronx multi-cross roll tube straightening machine will handle ferrous and non-ferrous tubes from $\frac{3}{8}$ in. to $3\frac{1}{2}$ in. dia.

Main features of the machine, shown in Fig. 9, are :—

(*a*) All rolls are driven ; (*b*) no guide bars are required between the rolls, therefore there is no marking of the material ; (*c*) the tube is held between three pairs of line contact rolls ; and (*d*) the rolls can be easily adjusted so that the tube is perfectly supported.

The drive to the rolls is taken from two totally-enclosed gear boxes with vee-belt drive from two motors, and to permit full adjustment of the rolls, universal couplings and spindles are fitted between the rolls and the gear drives.

All three upper rolls are adjustable vertically to suit tube dimensions. In the case of the centre rolls both bottom and top rolls are adjustable vertically to enable the necessary deflexion to be applied to the tube. All rolls have angular adjustment for line contact setting.

This machine can be provided with single-speed motors to give a fixed straightening speed of 250 ft. per min. or with two- or three-speed motors to give a straightening speed up to 400 ft. per min.

Machines of this type are manufactured by Bronx Engineering Co. Ltd., Lye, Stourbridge, to cover a complete range of tubes from 0.020 in. up to 12 in. dia. Further details will be supplied on request.

(*Continued in page* 700)

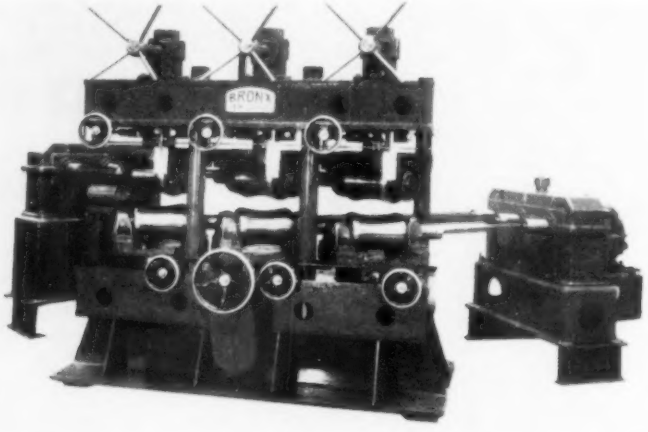
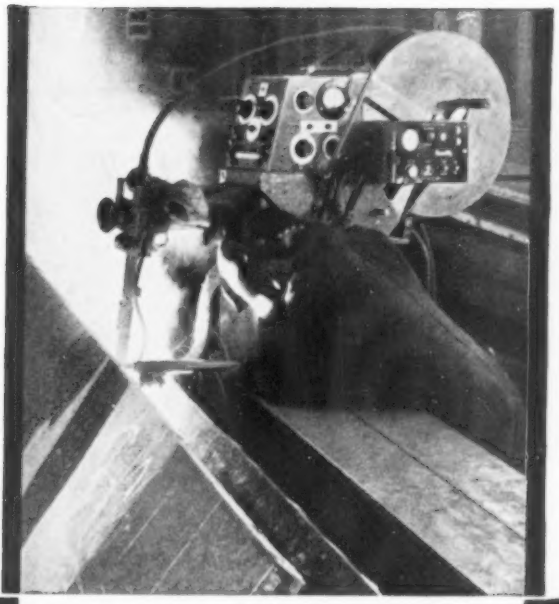


Fig. 9.—Tube straightening machine



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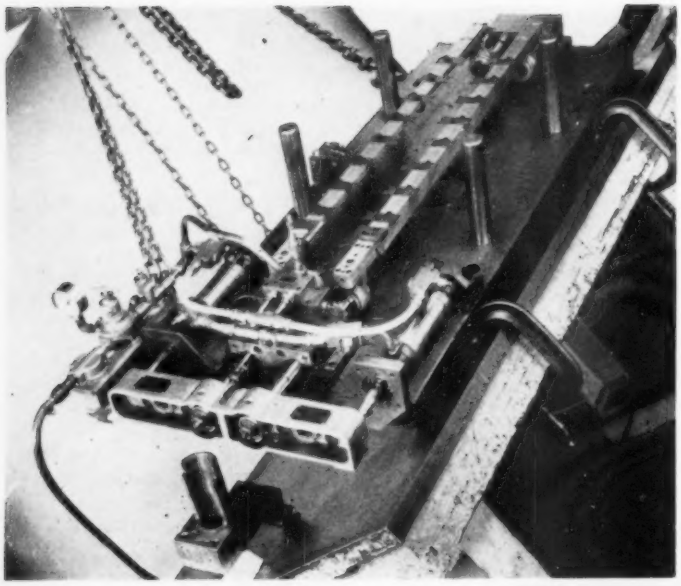

Fig. 10 (left).—Press transfer unit

Fig. 11 (below).—Temperature controller

Press Transfer Unit

FIG. 10 shows the press transfer unit manufactured by Turner Bros. (Birmingham) Ltd., Cleveland Street, Birmingham, 19.

The transfer arms carrying the transfer fingers are mounted on shafts carried in ball bushes which permit both rotary and linear motion. These shafts have on their outer ends Rotax ball thread units left- and right-hand threaded and of 3 in. pitch. The nuts of these are mounted in a cast aluminium cross-head to which is also connected the driving medium whether air cylinders or a link from the press crankshaft. Between the transfer arms at one end is a track block which is fitted with pawls which govern the motion of the arms as follows :—

1. The initial forward movement of the cross-head produces an inwards radial movement of the transfer arms, since forward motion is prevented by the track block and the transfer fingers grip the components.
2. In this position the arms travel forwards carrying the components one pitch through the tools and at the end of their movement keys attached to the arms override pawls on the track block.
3. The movement of the cross-head is reversed (in the case of the pneumatic feed by a pilot valve being depressed at the end of the feed stroke) and since the transfer arms are prevented from returning on their original path by the pawl, the transfer arms open outwards leaving the components in position on the dies.
4. The transfer arms return to their starting position again overriding a pawl on the track block at the extreme of travel.

When pneumatically operated the double-acting cylinders used are fitted with dampers at the beginning and end of their strokes in both directions to ensure smooth pick up and release of the components.

The mechanically operated unit can be fitted to any press adapted for use with a roll feed, *i.e.* with an extension on the crankshaft, to which can be fitted the cam and linkage for operating the unit in lieu of the pneumatic equipment.

Dual Zone Temperature Controller

A NEW mercury-in-steel, on-off temperature controller (Fig. 11), which has independent circuits allowing control at any two points through one instrument, has been produced by British Rototherm Co. Ltd., Merton Abbey, London, S.W.19.

Each of the two controller circuits consists of alloy steel Bourdon tubes, capillaries and temperature sensitive bulbs, operating mercury switches rated up to 30 amp. at 230/250 A.C. The differential is fixed but varies according to switching capacity.

Indicator lamps and bottom entry electrical conduit are standard. Temperature ranges are available between minus 20°F and plus 1000°F (minimum coverage 100°F) and the equivalent °C.

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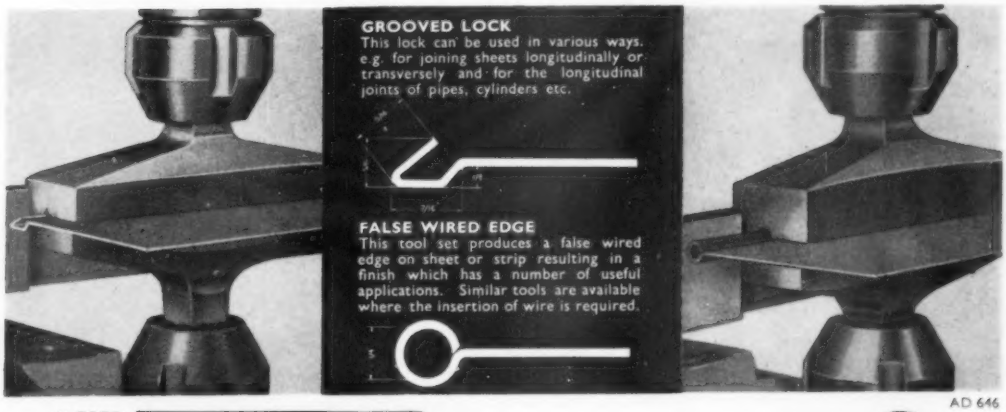
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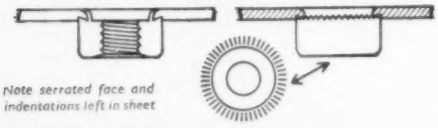

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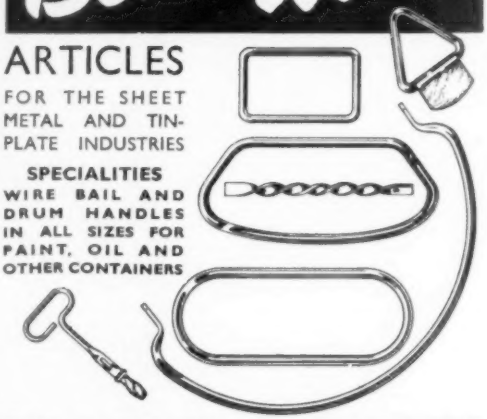

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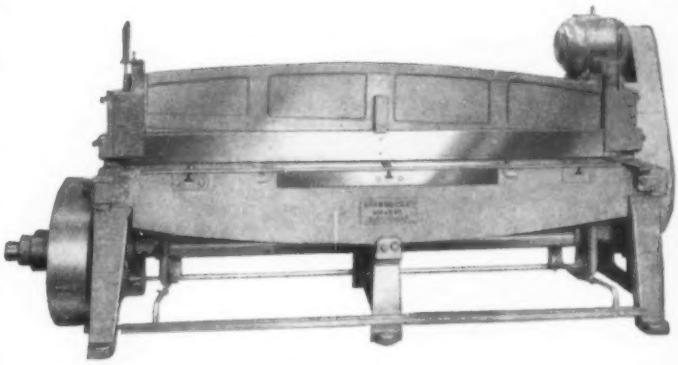

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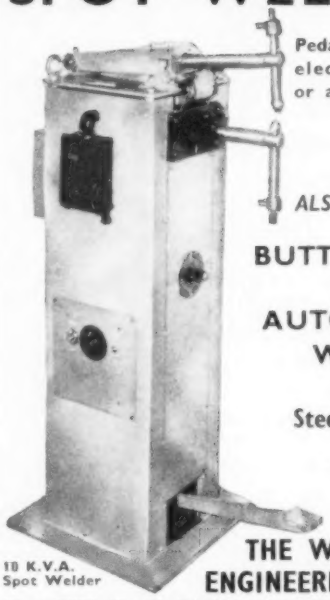

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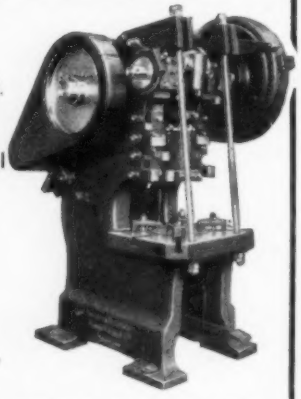

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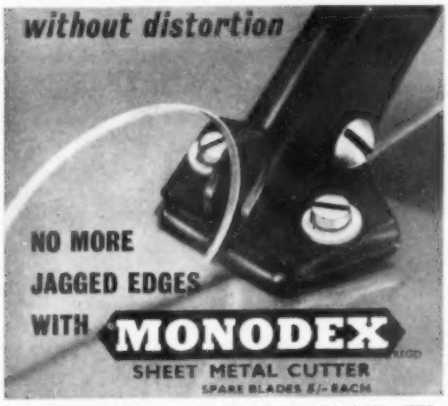

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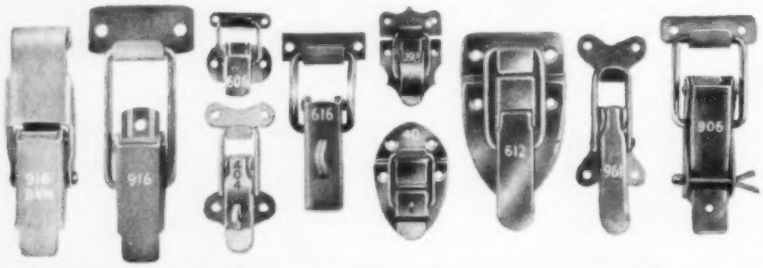

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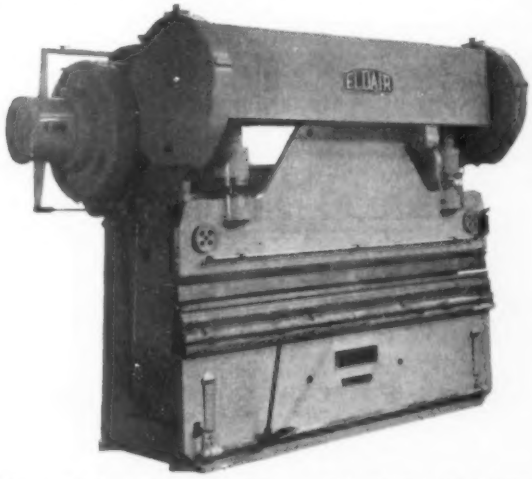

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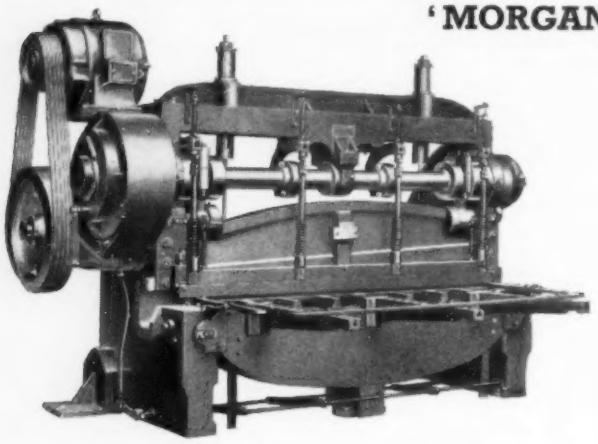

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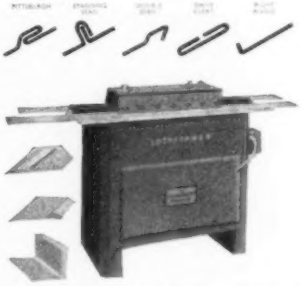

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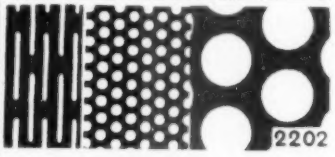

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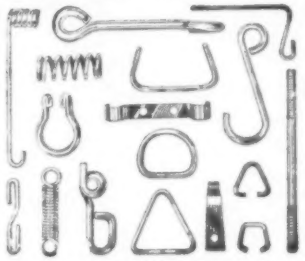

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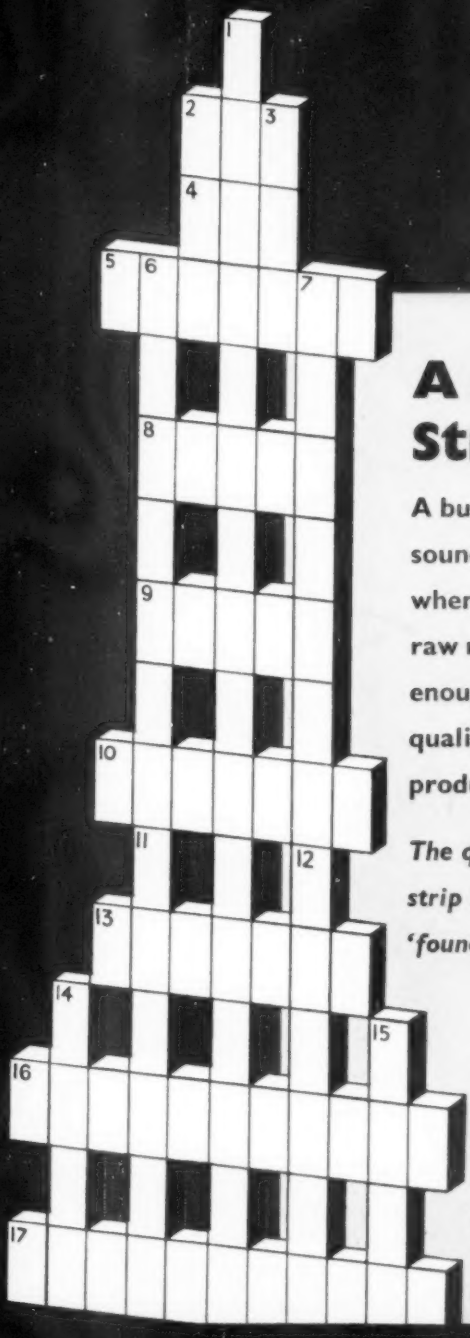

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9 Comparatively high-up person—most venomous (5)
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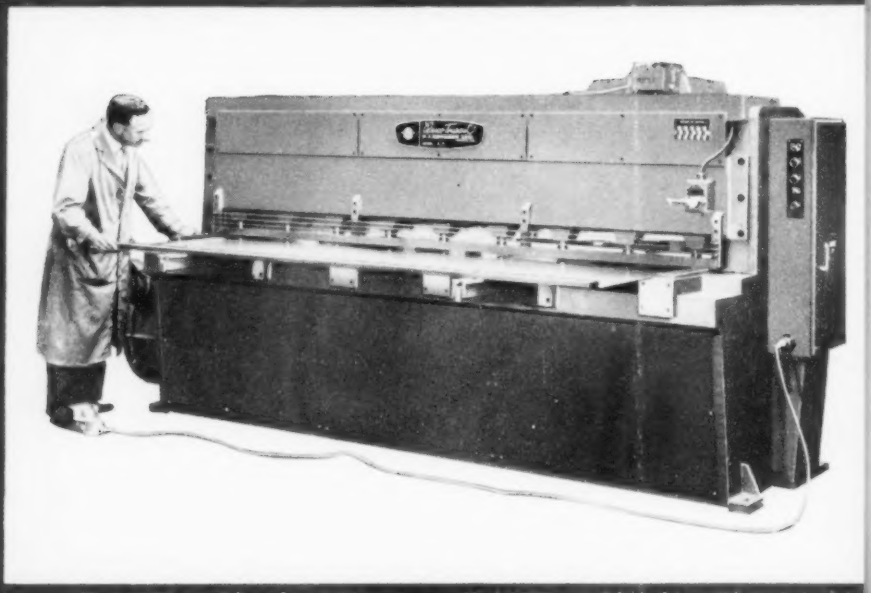

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